Deanship of Graduate Studies

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Evaluation and Enhancement of Jawwal GSM Network in Jenien City

Baha' Khaled Mkheimer

M.Sc. Thesis

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Evaluation and Enhancement of Jawwal GSM Network in Jenien City

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December, 2011

Dedication

For my dear Father for his tremendous support and great passion,

For my Mother for her great efforts, endless concern and love,

For my Best Brother Hamdan for his strong believe in me and being a excellent listener,

For my sisters Reem and Laila for their great love and support,

For my Supervisor Dr. Ali Jamoos for his continuous support, valuable comments and great guidance through this research,

For my manager Mr. Assem Asad for his ultimate support and precious comments,

For all my colleagues at work in Jawwal, who inspired me by their innovations.

For all my friends who inspire me and add joy to my life,

I dedicate this work.

Declaration

I Certify that this thesis submitted for the degree of Master is the result of my own research, except where otherwise acknowledged, and that this thesis (or any part of the same) has not been submitted for a higher degree to any other university or institution.

Signature: Baha' Mkheimer.

Baha' Khaled Mkheimer.

Date: 21/12/2011.

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Abstract

Mobile communications is one of the main industries that pumps money to the world economy. The most known and profitable standard is the Global System of Mobile communications (GSM) which was introduced in 1982.

This thesis aims at evaluating and enhancing the performance of the Palestine Cellular Communications Co. "Jawwal" GSM network in Jenien City. This research is conducted from August, 2010 till October, 2011.

The initial evaluation of Jawwal GSM network in Jenien city showed that about 0.8% of the initiated connections are dropped after the resources are assigned from the network to the customer. This is called Traffic Channel drop rate (TCH drop rate). In addition, about 8% of the collected samples from the drive test of Jenien city lies in level 4 which is the worst level in terms of signal quality and strength. Moreover, only 65.5% of the collected samples from the drive test lies in level 1, which is the best level in terms of signal quality and strength.

The above issues are the driving forces to perform this research. Thus, it is required to enhance the network performance for Jawwal GSM network in Jenien city while taking into account the limited number of available channels (24 channels for both traffic and control) and the increasing number of subscribers.

The ultimate objective of this thesis is to reduce the TCH drop rate and to reduce the percentage of the samples that lies in level 4 while increasing the percentage of the samples that lies in level 1.

Two approaches are adopted in this thesis to evaluate the performance of GSM network in Jenien city. The first approach is the Key Performance Indicators (KPI), which are counters in the Operation and Support Subsystem (OSS) of the GSM network. KPIs are statistical data that are processed and displayed to give us a meaningful picture about GSM cell behavior. The second approach is the drive test. In the drive test, a professional tool preinstalled on a laptop is used to record a log file that contains data extracted from Mobile Station (MS). These data reflects the user's experience since it uses regular MS. The collected data includes received signal strength and signal quality. In addition, it registers events from call setups, drop calls and handover.

In this research, these two methods are used to evaluate the performance of GSM network in Jenien city in terms of traffic drop rate, signal strength, and interference.

After evaluating Jawwal GSM network in Jenien City, it is found that the co-channel interference is the main issue that results in poor signal quality during the call or even during the call setups. In addition, high interference is found to affect the control channels mainly the Broadcast Control Channels (BCCHs).

In the case of Jenien city, the available 24 channels are divided into 16 for Traffic Channels (TCHs) and 8 for BCCH. The fact that only 8 BCCHs are reused in 57 GSM cells of Jenien city makes it reasonable to have a high level of interference on the BCCH. The solution for this issue is to increase the BCCHs but that is not allowed because of the Israeli restrictions. Any increase of the number of BCCHs will decrease the TCHs which are directly connected to capacity. This leads us to capacity analysis. A new TCH and BCCH frequency plans are proposed to improve the traffic drop rate, reduce the interference level and boost the quality of service (QoS). The proposed plans are implemented into the network after several optimization steps. Two kinds of optimization procedures are adopted. The first one is manual

optimization while the second one is by using specific OSS optimization tools. The two optimization approaches ensures that every cell has the best BCCH and TCH with the least interference.

According to the comparative study we carried out between the performance of the network before and after the enhancement, the average TCH drop rate is reduced from 0.76% to 0.62%. In, addition, the percentage of samples in level 1 is increased from 65% to 76% while the percentage of samples in level 4 is decreased from 7.76% to 5.16%.

ملخص الرسالة

يعد النظام العالمي للاتصالات الخلوية (**GSM**) الذي تم الكشف عنه أول مرة عام 1982 الأكثر استخداما حتى يومنا هذا، حيث يشكل هذا النظام رافداً أساسيا للاقتصاد العالمي وقد تم اعتماد هذا النظام من قبل شركة الاتصالات الخلوية الفلسطينية (جوال) .

تهدف هذه الدراسة إلى تقييم و تحسين أداء شبكة جوال، حيث تم اختيار مدينة جنين كحالة للدراسة.

اشارت النتائج الأولية لتقييم أداء شبكة جوال في مدينة جنين الى ان حوالي 0.8% من المكالمات المنشأة عن طريق الشبكة تعاني من انقطاع أثناء المكالمة. أيضاً، اشارت النتائج الأولية الى ان حوالي 8% من العينة التي تم جمعها للشبكة تشير الى ضعف في التغطية أو سوء في جودة الخدمة أو كلتيهما وهي تأتي ضمن المستوى 4 الذي هو أسوأ مستوى من حيث قوة و جودة الاشارة. بالاضافة الى أن 65.5% فقط من تلك العينة تقع ضمن المستوى 1 و هو أفضل مستوى من حيث قوة و جودة الاشارة.

النتائج انفة الذكر هي الدوافع الرئيسية للقيام بهذا البحث. هذه الرسالة تهدف الى التقليل من انقطاع المكالمات و تقليل نسبة العينة التي تقع في المستوى 4 و زيادة نسبة العينة في المستوى 1 مع الأخذ بعين الاعتبار أن عدد القنوات المتاحة لشركة جوال هي فقط 24 قناة وأن عدد مستخدمي شبكة جوال أخذ في الازدياد.

في هذه الرسالة، تم استخدام طريقتين لتقييم و تحسين أداء شبكة جوال في مدينة جنين وهما **Drive Test** و **KPIs**. الطريقة الاولى **KPIs** هي طريقة احصائية تقوم على تسجيل كافة المعلومات الواردة من الشبكة و تحليلها ومن ثم عرضها لاظهار صورة واضحة عن الشبكة. هذه طريقة سريعة و فعالة لمراقبة الشبكة و تقوم باعطاء نتائج فورية و لكن تفتقر الى تحديد مكان المشكلة بعكس التقنية الثانية **Drive Test**. في هذه التقنية تقوم هواتف متصلة بحاسوب باجراء مكالمات أثناء السير بسيارة لمحاكاة المستخدم العادي لهذا النظام. ويقوم الحاسوب بتسجيل كافة المعلومات و من ثم يقوم الشخص المتخصص بتحليل تلك المعلومات و التعرف على المشاكل ومن ثم حلها. الناحية الايجابية في هذه الطريقة هي اعطاء وجهة نظر المستخدم للشبكة.

بعد جمع كافة المعلومات عن الشبكة باستخدام الطريقتين و تحليل هذه المعلومات بشكل دقيق تبين أن المشكلة هي التداخل (التشويش) على قنوات التحكم و المكالمات والذي ينتج عن اعادة استخدام القنوات في مناطق جغرافية متقاربة, وتم التوصل الى أن المشكلة الأكبر كانت التداخل على قنوات التحكم والذي يؤدي بدوره الى فصل المكالمات أثناء انشاء المكالمة.

تستخدم جوال 24 قناة اتصال كقنوات تحكم و قنوات مخصصة للمكالمات و قد كانت القسمة هي 16 قناة مخصصة للمكالمات و 8 قنوات مخصصة للتحكم وهذا أدى الى مستوى تداخل عالي في قنوات التحكم. بعد دراسة الوضع تبين أن زيادة عدد قنوات التحكم سيكون له الأثر الأكبر في تقليل مستوى التداخل و لكن سيكون هذا على حساب القنوات المخصصة للمكالمات. لذا، قمنا بدراسة تحليلية لمعرفة مدى استيعاب الشبكة للمكالمات حتى نرى ان كان هناك امكانية تقليل القنوات المخصصة للمكالمات.

بعد دراسة شاملة تم التوصل الى ان تحسين اداء الشبكة يكمن في اعادة توزيع تلك القنوات بين قنوات خاصة بالتحكم و قنوات خاصة بالمكالمات. تهدف فكرة هذه الطريقة الى تقليل انقطاع المكالمات و تقليل مستوى التداخل الذي بدوره يؤدي الى تحسين جودة الخدمة. و قد تم التوصل الى ذلك الحل بعد عدة عمليات من التوليف على مرحلتين هما التوليف اليدوي و التوليف بواسطة أدوات SSO .

من الجدير بالذكر هنا بأنه لا توجد هناك زيادة اضافية في الاستثمارات المالية حيث أنه لم يتم تغيير على المعدات المستخدمة.

وفقا للدراسة المقارنة بين وضع شبكة جوال في مدينة جنين قبل وبعد استحدث التغيرات السابقة الذكر، تبين أن كفائة الشبكة تحسنت بشكل ملحوظ حيث ان نسبة انقطاع المكالمات قلت من 0.76% الى 0.62%. بالإضافة، تبين أن نسبة العينة في المستوى 1 ارتفعت من 65% الى 76% بينما انخفضت نسبة العينة في المستوى 4 من 7.76% الى 5.16%.

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Acronyms

AGCH	Access Grant Channel
ARFCN	Absolute Radio Frequency Channel Number
AUC	Authentication Center
BCCH	Broadcast Control Channel
BCCHNO	BCCH Number
BSC	Base Station Controller
BSIC	Base Station Identity Code
BSPWRB	Base Station Power for BCCH carrier
BSPWRT	Base Station Power for TCH carrier
BSS	Base Station Subsystem
BTS	Base Transceiver Station
C/A	Carrier to Adjacent interference ratio
C/I	Carrier to Interference ratio
CHGR	Channel Group
CSF	Call Setup Failure
DC	Dropped Call
DL	Down Link
DTI	Data Transmission Interface
EIR	Equipment Identity Register
FACCH	Fast Associated Control Channel
FAS	Frequency Allocation Support
FCCH	Frequency Correction Channel.
GMSC	Gateway MSC.
GMSK	Gaussian Minimum Shift Keying
GPS	Global Positioning System
GSM	Global System of Mobile communications
HF	Handover Failure
HLR	Home Location Register
HOP	Hopping for frequency
HR	Half Rate
HSN	Hopping Sequence Number
ILR	Interworking Location Register
KPI	Key Performance Indicator
MAIO	Mobile Allocation Index Offset
MRR	Measuring Result Recording
MS	Mobile Station
MSC	Mobile Switching Center
NCS	Neighbor Cell Support
NCS	Neighbor Cell Support

OSS	Operation and Support Subsystem
PCH	Paging Channel
RACH	Random Access Channel
RXLEVSUB	Received Level
RXQUALSUB	Received Quality
SACCH	Slow Associated Control Channel
SCH	Synchronization Channel
SDCCH	Standalone Dedicated Control Channel
SIR	Signal to Interference ratio
SMS	Short Messaging Service
SMS-GMSC	Short Messages Service GMSC
SS	Switching Subsystem
TA	Timing Advance
TCH	Traffic Channel
TDMA	Time Division Multiple Access
TEMS	TEst Mobile System
TRU	Transceiver Unit
TS	Time Slot
UL	Up Link
VLR	Visitor Location Register

Chapter 1

Introduction

Global System for Mobile communications (GSM), the three letters that makes a revolution in mobile communications, is the most widely spread mobile communication system all around the world. GSM provides several telecommunications services such as voice calls, data sessions, Short Messaging Service (SMS), Multimedia Messaging Services (MMS), etc. Let us take a flash back to the history of this technology.

In 1982, the *Poste Télécommunications et Télédiffusion* (PTT) sent a proposal to *Conférence Européenne des Postes et Télécommunications* (CEPT) to specify a common European telecommunication service in the 900 MHz band. GSM standardization group was then established to formulate the specifications for this european mobile cellular radio system. From the year 1982 to 1985, discussions centered around whether to build an analog or a digital system, where GSM decided to develop a digital system. In 1986, companies participated in a field test in Paris to determine whether a narrowband or broadband solution would be deployed. By May 1987, the narrowband Time Division Multiple Access (TDMA) solution was chosen. Concurrently, operators in 13 countries (two operators in the United Kingdom) signed the Memorandum of Understanding (MoU) which committed them to fulfill GSM specifications and deliver a GSM system by July, 1991 [1]. As compared with other technologies, GSM dominates about 80% from the total number of subscribers which is about 4,310,295,611 subscribers in the second quarter, 2009 [2].

After this flash back on the history of the GSM, let us go deep in this technology and explore it more extensively.

GSM is a system that consists of three subsystems that all make a complete and operational system as will be pointed out in the following subsections.

1.1 GSM System Architecture

GSM system architecture is divided into three subsystems: the Base Station Subsystem (BSS), Operation and Support Subsystem (OSS), and Switching Subsystem (SS). The complete GSM system architecture is shown in figure 1.1. The GSM subsystems can be explained briefly as follows:

1.1.1 Base Station Subsystem (BSS)

The BSS consists of the Base Station Controller (BSC) and Base Transceiver Station (BTS), as shown in figure 1.2.

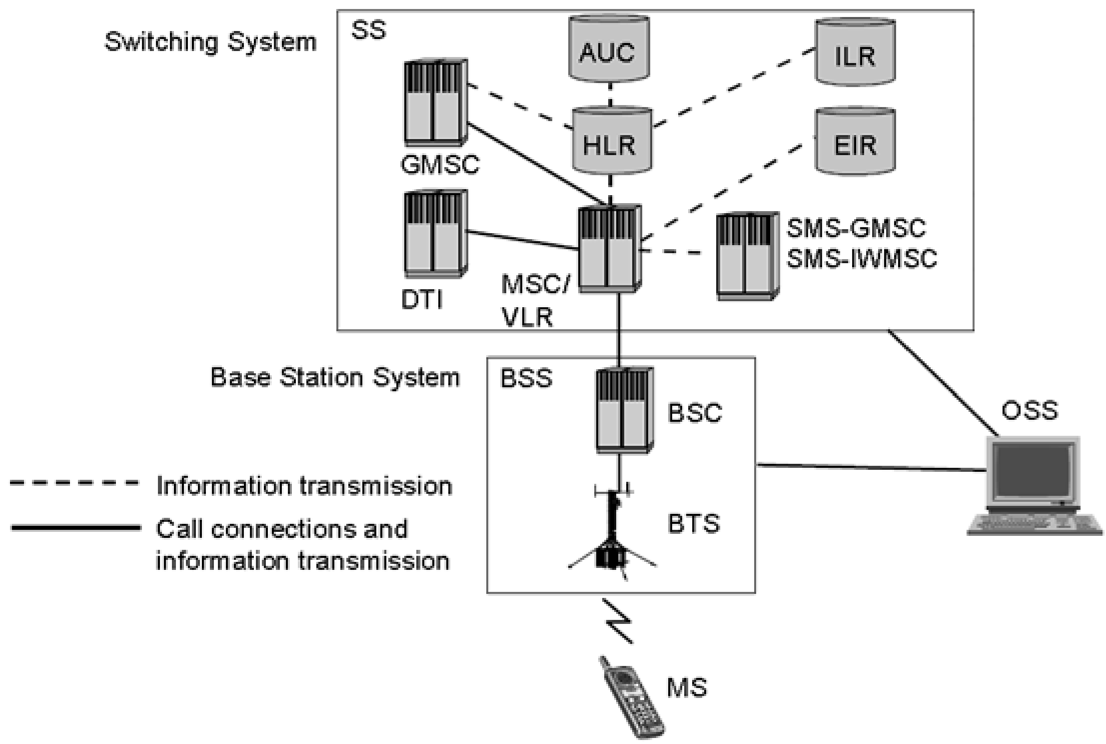


Figure 1.1: GSM system architecture.

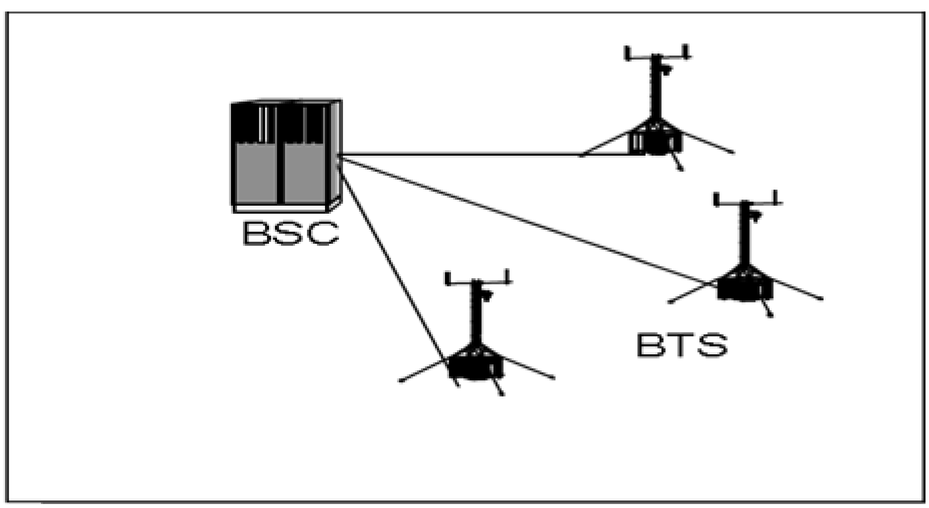


Figure 1.2: Base Station Subsystem.

a) BTS:

The BTS includes all radio and transmission interface equipment needed in one cell. BTS uses frequency to operate and serve the users. One frequency is used to transmit signals to the mobile station and one to receive signals from the mobile station. For this reason at least one transmitter and one receiver is needed. The unit in the BTS that is responsible about transmission/reception is called Transceiver Unit (TRU).

b) BSC:

It is the central part of the BSS. It is used to manage the entire radio network and performs the following functions:

- Handling of the mobile station connection and handover.
- Radio network management.
- Transcoding and rate adaptation.
- Traffic concentration.
- Transmission management of the BTSs
- Remote control of the BTSs.

1.1.2 Operation and Support Subsystem (OSS)

OSS is the part of the GSM system used for administration, database and network operation support. OSS supports the network operator by providing some tools for monitoring and controlling the network. It includes the following tools:

a. Cellular network administration: used as database for all the cell parameters. In addition, it is used as user interface to change these parameters.
b. Network operation support: used to give the operator the support when operating new cells.
c. Radio network optimization: this tool is extensively used in designing the parameters for a live network based on a real measurement.

Moreover, the OSS provides us with a powerful tool which is the Key Performance Indicators (KPIs). These indicators give indication about the behavior of the GSM cell at a given time. The OSS, in cooperation with other software, is used to evaluate the performance of the GSM cells by using counters located at the BSC. These counters of events include dropped calls, handovers, etc. Detailed description for these KPIs will be presented in chapter 3. Another advantage of the OSS is the radio network optimization tools. These tools are used for optimizing the performance of the GSM cells as will be explained in chapter 5.

1.1.3 Switching Subsystem (SS)

The SS is responsible for routing calls between mobile stations among the GSM network. The SS consists of the following units:

a) Mobile Switching Center (MSC): is the heart of the GSM network, responsible about set-up, routing, and supervision of calls to and from mobile subscribers.
b) Home Location Register (HLR): Each GSM operator has a database containing information about all subscribers belonging to the specific Public Land Mobile Network (PLMN).

c) Visitor Location Register (VLR): In the Ericsson GSM based solution, the VLR is integrated with the MSC. This is referred to as the MSC/VLR. The VLR contains non-permanent information about mobile subscribers visiting the MSC/VLR service area.
d) Authentication Center (AUC): For security reasons, speech, data, and signaling are ciphered. The AUC provides authentication and encryption parameters required for subscriber verification and to ensure call confidentiality.

1.2 Physical and Logical Channels

GSM standard uses Time Division Multiple Access (TDMA) as multiple access technique. In TDMA, the radio channel is shared between the subscribers such that each subscriber has a Time Slot (TS) to access the same radio channel. Each TS in a given radio channel is called a physical channel. When the physical channel is used to carry traffic or control information it is called logical channel.

1. Physical Channels:

GSM 900, GSM 1800 and GSM 1900 are the common three GSM bands. These bands come to fulfill the needs of the increasing number of demanding customers. The most common GSM band is the 900 MHz band which is used in Jawwal GSM network. Each band is divided into two sub-bands which are called Up Link (UL) from the Mobile Station (MS) to the BTS and Down Link (DL) from the BTS to the MS. The idea behind this separation is to have two separate frequency bands to provide the user with full duplex communication service. The details of the three common GSM bands are shown in table 1.1.

Frequency band (MHz)	UL frequency range (MHz)	DL frequency range (MHz)
GSM900	890-915	935-960
GSM1800	1710-1785	1805-1880
GSM1900	1850-1910	1930-1990

Table 1.1: Various GSM frequency bands.

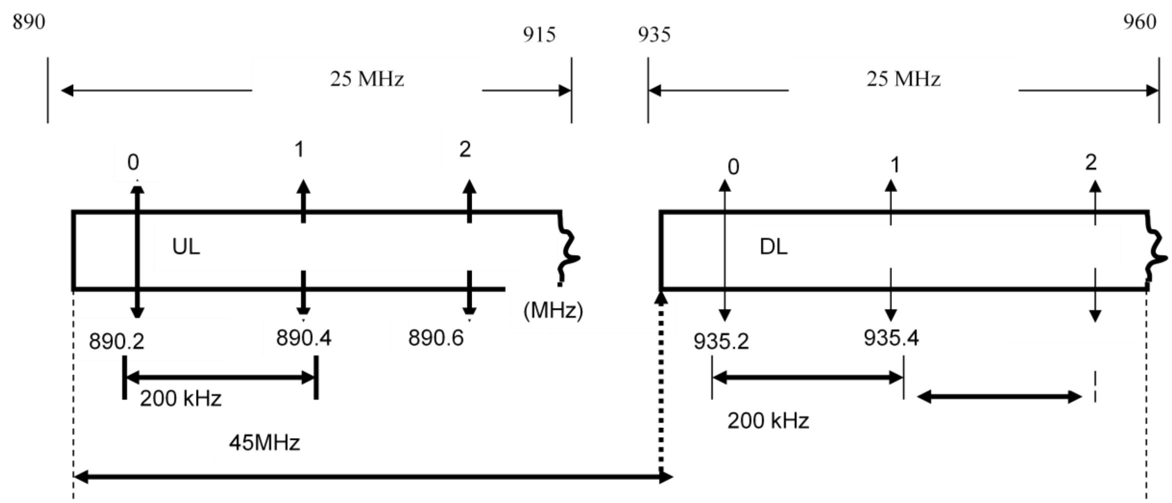


Figure 1.3: GSM 900 band with UL, DL, channel bandwidth and duplex distance.

GSM900 offers us 25 MHz bandwidth for each of the UL and DL as shown in Figure 1.3. Each of these 25MHz bandwidth is divided into 200 KHz radio channels yielding 125 physical channels among which one channel is reserved for synchronization. The remaining 124 physical channels are usually numbered from 1 to 124 and are called Absolute Radio Frequency Channel Number (ARFCN). The corresponding number of ARFCNs for GSM 1800 and GSM 1900 are 374 and 299, respectively.

The TDMA frame consists of eight TS as shown in Figure 1.4. Each TS is 0.577 ms long and has room for 156.25 bits (148 bits of information and a 8.25 bits long guard period). 114 bits are used to carry the user data bits. 26 bits are used for training the equalizer at the receiver side. Two Stealing bits (S) are used to specify whether the user data bits carry traffic or control information. 6 bits are used as tail bits to indicate the start and the end of the information bits. 8.25 are the guard space bits for separating two successive TDMA frames.

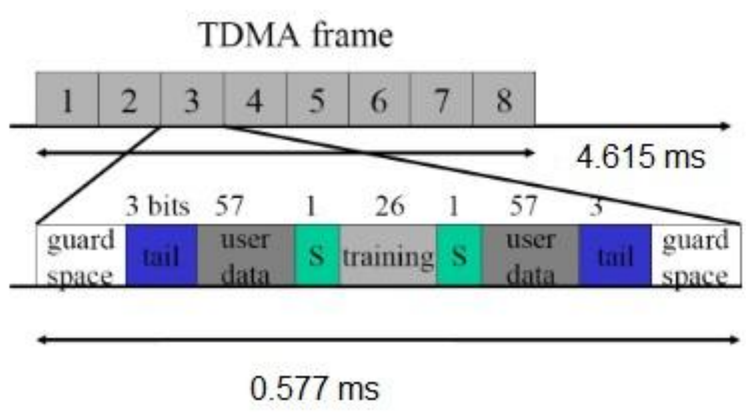


Figure 1.4: TDMA frame, Time Slot (TS) and Burst structures.

2. Logical Channels:

On every physical channel or ARFCN, a number of logical channels are mapped. Each logical channel is used for specific purposes, e.g., paging, call set-up signaling or speech. There are eleven logical channels in the GSM system. Two of them are used for traffic and nine for control. Let us start by the traffic channels.

A. Traffic Channels (TCH): used to carry user traffic. The TCHs are categorized as follows:

   1. Full Rate (FR) channel: this channel can be used for full rate or enhanced full rate speech (13 Kbit/s after speech coder) or data up to 9.6 Kbit/s.
   2. Half Rate (HR) channel: this channel can be used for HR speech (6.5 Kbit/s after speech coder) or data up to 4.8 Kbit/s.

B. Control channels: Nine different types of control channels are used, and they are categorized as follows:

   1. Broadcast Channels (BCH):
      a. Frequency Correction Channel (FCCH): Used for frequency correction of the MS, downlink only.
      b. Synchronization Channel (SCH): Carries information about TDMA frame number and Base Station Identity Code (BSIC) of the BTS, downlink only.
      c. Broadcast Control Channel (BCCH): Broadcasts cell specific information to the MS, downlink only.

   2. Common Control Channels (CCCH):
      a. Paging Channel (PCH): Used to page the MS, downlink only.
      b. Random Access Channel (RACH): Used by the MS to request allocation of a Stand Alone Dedicated Control Channel (SDCCH), either as a page response or an access to MS call origination/registration, location updating, etc. uplink only.
      c. Access Grant Channel (AGCH): Used to allocate SDCCH to a MS, downlink only.

   3. Dedicated Control CHannels (DCCH):
      a. Stand alone Dedicated Control Channel (SDCCH), Used for signaling during the call set-up or registration, uplink and downlink.
      b. Slow Associated Control Channel (SACCH), Control channel associated with a TCH or a SDCCH, uplink and downlink. On this channel the measurement reports are sent on the uplink, and timing advance and power orders on the downlink. The SACH period is 480 ms.
      c. Fast Associated Control Channel (FACCH), Control channel associated with a TCH, uplink and downlink. FACCH works in bit-stealing mode, i.e. 20 ms of speech is replaced by a control message. It is used during

handover when the SACCH signaling is not fast enough. Since about 0.5 s may cause a call to be dropped, FACCH is used in 20 ms in the handover.

Several logical channels can share the same physical channel or TS. On TS0 the BCCH carrier and the common control channels are multiplexed [3].

1.3 Important Parameters in GSM

There are plenty of parameters used in GSM system. The parameters are divided into cell parameter, BSC parameter, and MSC parameter. In this thesis we will focus on cell parameters and provide the definition of some of them.

1. BCCH:

This is the control frequency that carries the BCCH in a cell. The definition of this parameter means that a given ARFCN is assigned as BCCH frequency for a given cell. Note that different cells may have the same BCCH ARFCN due to the reusing of the same frequency for more than one cell in order to improve the capacity of the GSM system.

2. BSIC:

Base Station Identity Code (BSIC), which is used with the BCCH as BCCH/BSIC to identify each cell in GSM by the BSC and MS. This stamp is used to identify the cells with the same BCCH (co-channel cells). The Cells with common BCCH/BSIC are accepted in the same BSC unless they are not neighbors.

3. BSPWRB:

Base Station Power for BCCH (BSPWRB) in dBm which is the power for the BCCH ARFCN. This parameter is BTS dependent. Ericsson BTS accepts only odd values for this parameter. Usually BSPWRB should be set to maximum value the BTS can handle, unless it's intended to shrink the coverage for a given cell this power parameter may be reduced.

4. BSPWRT:

Base Station Power for TCH (BSPWRT) ARFCN in dBm is the power for the non-BCCH ARFCN. Only Odd value accepted with Ericsson BTS models. It is commonly that BSPWRB and BSPWRT both have the same values.

5. CHGR:

A cell is divided into one or more channel groups (CHGR) that contain all physical channels. Usually the CHGR_0 is assigned to the BCCH and CHGR_1 is for the TCHs.

6. DCHNO:

Dynamic Channel Number (DCHNO) is the ARFCNs which defines the TCHs in a given CHGR (commonly CHGR_1).

7. HOP:

Hopping (HOP) status identifier, with ON or OFF values. This feature should be activated on TCH channels to minimize the interference among these channels. This feature aims to manipulate the TCHs in a way such that the collision between the same frequencies is minimized. This results in interference reduction on these frequencies. Hopping must be deactivated on the BCCH carrier since each cell must continuously broadcast this control data.

8. HSN:

Hopping Sequence Number (HSN) takes values from 0 to 63. As there is no hopping in CHGR0, the HSN should have NULL value. The HSN should be given to the cell for CHGR_1 (TCHs) to reduce the interference among TCHs.

9. SDCCH:

It is the required number of SDCCH. Up to 32 SDCCH can be specified per cell. It is recommended to set the SDCCH to (Number of TRUs - 1).

10. MAIO:

The Mobile Allocation Offset Index (MAIO) is the ARFCN that is assigned to the traffic channels. The MAIO list in each cell depends on the number of TRUs in that cell and is given by:

$$\boldsymbol{MAIO} = \#\,\boldsymbol{TRUs} - \mathbf{1} \qquad (2.1)$$

This MAIO list is hopped according the HSN which generates pseudo random manipulation for these TCHs so the chances of interference are minimized [3].

11. Neighbor relations

The neighbor relation is a very effective technique for reducing interference. It is normal that the received signal from a specific cell is reduced as MS is moving away from that cell. Thus, at a given point another cell called "neighboring cell" will be better than the currently serving cell. When two cells are neighbors , the MS will be handed over during the call to the other cell. Neighbor relation can be single or mutual meaning that handover will be done in one direction or in both directions, where the last case is the most common one. It is very critical to note that the neighbor cells must not have the same BCCH frequency to avoid interference on that carrier [4].

1.4 Frequency Reuse and Co-Channel Interference

There is nothing infinite in real life and ARFCN is no exception, so we have only 124 ARFCN in GSM900 band. In addition, operators in the same country share these resources. This lead to the use of the same frequency in different geographical locations leading to the concept of frequency reuse. The main advantage of frequency reuse is increasing capacity. However, frequency reuse results in co-channel interference which is the interference between cells that use the same frequencies (channels). By reusing the channels according to well-proven reuse patterns, co-channel interference can be minimized. The Carrier-to-Interference (C/I) ratio is commonly used to measure the relative signal strength between the desired carrier signal and the interference.

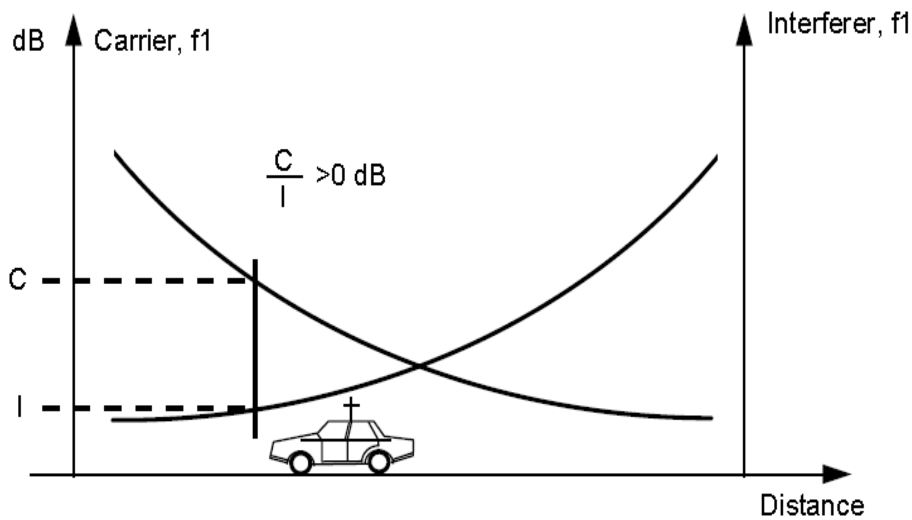


Figure 1.5: Carrier-to-Interference (C/I) ratio versus distance as the mobile moves toward the base station.

The GSM specification states that C/I ratio must be larger than 9 dB. On the other hand, Ericsson recommends using C/I >12 dB as a planning criterion. If frequency hopping is implemented, it adds extra diversity to the system corresponding to a margin of approximately 3 dB, i.e. while C/I > 12 dB when no frequency hopping is used, only C/I > 9 dB is required when frequency hopping is used.

1.5 Literature Survey on GSM Network Evaluation and Enhancement

There are several research papers in the literature that address evaluation and enhancement of GSM networks [5]-[18].

In [5], the authors stated that KPIs are counters of the BSC which are converted to more readable way by mathematical expressions. Call setup success rate, call drop rate, handover success rate and traffic congestion are the main KPIs that the author used in performance evaluation for alive network. Every KPI is explored and the improvement methodologies are listed. The authors took an example of traffic congestion. They define that KPI as “the rate of blocked calls due to resources unavailability" and the possible reasons for that are hardware faults, increased traffic due to increased subscribers in a certain areas. In addition, they provided the cure of traffic congestion which is first to identify its reason then solve it. Half rate codec, adding TRUs or even using special portable sites that are called Cell On Wheels (COW) are among theses methodologies. However, the authors of [5] did not take a case study of a given area. In addition, they did not try to implement the "improvement methodologies" and find the results after the implementation. On the other hand, in our research the current KPIs are stated and recommendation will be proposed to enhance the network performance. These recommendations will be applied and then followed by another round of KPIs collection.

In [6], the authors consider alive GSM network under exposure and examine the traffic handled by that network in details to find the peak carried traffic and at what hour it occurs. They also spoke about the variations in traffic from weekdays to weekends and use these data to make a traffic model. The authors are interested in the traffic congestion since it is the most related KPI to their work . After that the authors start with the experimental part in which they consider part of a GSM operator in North America which includes one MSC, 4 BSCs and several BTSs with monitoring period of eight months. They provided detailed tables of BSCs utilization and congestion in addition to determine the peak hour. They also find that the weekends differ from regular weekdays in terms of traffic. A traffic model is then introduced which aims to help RF engineers to predict the traffic so as they can adapt their plans and avoid traffic congestion. Nevertheless, the authors in [6] didn't implement their suggestions in the site, BSC or MSC levels. On the other hand, in this research, a comprehensive capacity study will be carried out for all the sites in Jenien city. In addition, the peak traffic for each cell will be determined and at what time. This could lead to reconfigure the sites by assigning more or less traffic channels to the different cells. Thus, some changes will be recommended and implemented, and the performance of the network will be monitored after the implementation step.

The authors of [7] handle the topic of GSM network audit and optimization. They start by network audit and recommendations, then performing an optimization step and finally evaluating their work. The network audit is performed for all the network in order to identify and mark the poor performance in some areas, spot the inconsistencies and make recommendations to solve these problems. In addition, they categorized the audit into collecting information, analyzing them and suggesting some recommendations. For that step, the authors provide flow chart of the overall process. KPIs are the next topic that is addressed by the authors and includes monitoring all the GSM common KPIs with some explanations and formulas to calculate these KPIs. Moreover, the main reasons for poor KPIs behavior are introduced. Furthermore, competitive benchmarks which are used to compare the coverage and QoS between two operators serving the same area are addressed. Coverage plots of a two operators are given and the QoS plots are listed. Nevertheless, the recommendations that are used in optimization process need more clarification. In addition, the comparison between the two areas is not clear. On the other hand, at this research the recommendations are adopted to enhance the KPIs and compare the results before and after the implementation. In addition, benchmarks reports will be provided.

In [8], the performance of the GSM and GPRS operational network is presented. The authors give a quick review of the most common KPIs that are used to evaluate the performance of GSM and GPRS network. These KPIs are presented with short description, the relations between these KPIs are introduced and specific values for some KPIs are listed so that the GSM operators should not exceed them. Then, scenarios of the KPIs with different traffic cases are introduced to study the effect of traffic congestion on these KPIs. The contribution in this paper is that thresholds for different KPIs are introduced. These thresholds for the different KPIs will be adopted at our research.

In [9], a report by Ericsson, starts with short description of the main KPIs, possible reasons for poor performance of these KPIs. Then, it suggests ways to enhance these KPIs. As an example, let us take the TCH drop rate from Ericsson's point of view. First of all, they start explaining the way that traffic channels are established and released. In addition, the possible reasons for TCH drop are pointed out which include low signal strength, bad quality and suddenly lost in connection. Then, the report provides a short description about the most important parameter related to the TCH drop which is Radio Link Time Out (RLILKT). This parameter is decreased by one when the BTS receives no measuring report and increased by two when it does. Dropped call will occur when this timer reaches zero. After that, explanations for every possible reason of dropped calls are clarified and recommendations are made to enhance the TCH drop rate. If the sudden loss in connection is the main reason about dropped calls, the transmission faults, BTS hardware faults, handover lost and Mobile Station (MS) running out of battery during a call are the main issues regarding that reason.

In [10], the author in collaboration with Syrian Telecom provides a report about the radio network QoS and the tools used to evaluate the performance of GSM network. The network performance is defined as "The ability of a network or network portion to provide the functions related to communication between users". The author explains the two terms of QoS, one is a pure technical which is related to the overall performance of the network or part of it and the other is non-technical which is related to the customer satisfaction. Then, the standard KPIs of the GSM network are addressed with some details. Also, the thresholds for these KPIs are introduced. A measurement tools is used in order to judge the performance of GSM network such as drive test and TEst Mobile System (TEMS) from Ericsson and Actix as post-processing tool. Finally, the author mentioned some examples of poor KPI performance in a given area with help from some tools that they described previously but without proposing a recommendation for these issues. In this research, Booth KPIs and drive test are used to evaluate and enhance the performance of Jawwal network in Jenien city. Also in this research TEMS tool for drive tests is used. Actix is the post processing tool that is also used in drive test analysis.

The authors in [11] perform optimization of GSM network, data sorting and analyzing, implementing the optimization and system fine tuning. Network dimensioning such as BSC, MSC and other related parameters are addressed and the top ten wireless parameters are listed which are the most important from the authors' point of view. Finally, a case study is provided and discussed.

In [12], a semi automatic tool is developed to perform network optimization by tuning the parameters of alive GSM network. The authors select the most common KPIs to evaluate the QoS and they assign thresholds for these KPIs. They explained the algorithm behind this tool which was developed using Visual BASIC. This tool is then used to suggest some recommendations that must be applied to the cell to enhance its performance, and hence the overall network performance. A traffic congestion problem is presented and a flow chart of this problem is given to clarify the working mechanism of this tool. In this research, professional tools such as Actix and TEMS will be used to analyze the collected data. These tools are much more professional than the one used in [12].

1.6 Contributions of the Thesis

From the literature survey section above, some authors have suggested several approaches to improve the available KPIs. However, these approaches were not implemented and evaluated for alive GSM network. Other authors use the drive tests to evaluate the performance of active GSM networks in terms of QoS. Nevertheless, to the best of our knowledge, there is no comprehensive research works that combine both the KPIs and the drive tests to evaluate and enhance GSM mobile networks.

The contributions of this thesis can be summarized as follows [26]:

1) A comprehensive research study is carried-out on the performance evaluation and enhancement of Jawwal GSM mobile network in Jenien city[1].
2) Both the KPIs and the drive tests are combined to evaluate and enhance the performance of the GSM network in Jenien city. In addition, OSS optimization tools are used in the final optimization process.
3) A comparative study is carried-out between the performance of the GSM network before and after the enhancement.

Figure 1.6 illustrates the various research steps carried-out in this thesis. Starting from the already implemented Jawwal GSM network, an evaluation step is performed by using the data from network audit, KPIs and drive tests. After the evaluation step, an optimization step is performed followed by implementation. The optimization process is cyclic till the best performance for Jawwal GSM network in Jenien city is reached. At that point a comparative study is then carried-out between the performance of the GSM network before and after introducing the new implementation.

[1] Although we focus our attention on Jenien city as a case study, the proposed research work suggested in this thesis can be carried out for other cities in Palestine.

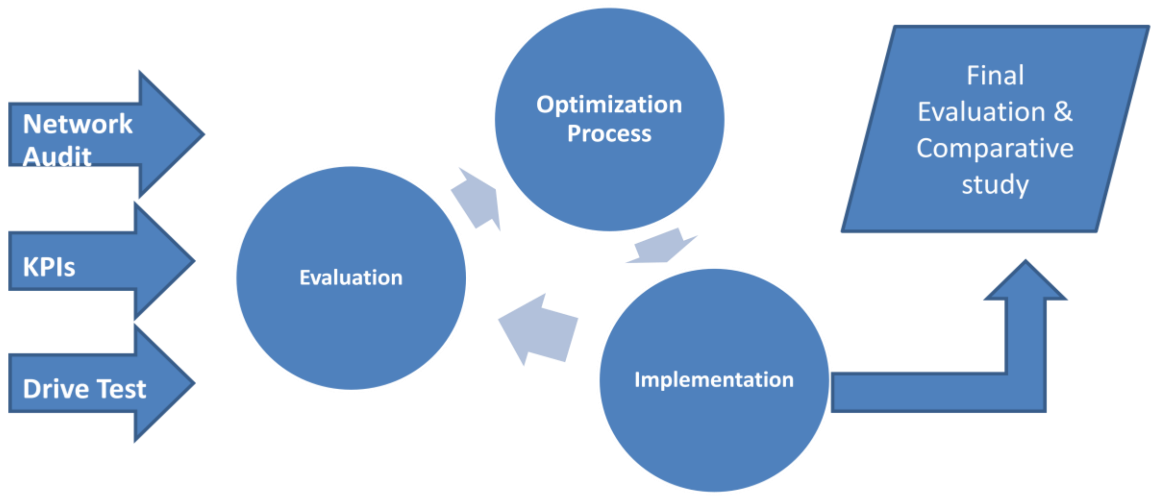


Figure 1.6: Research steps.

1.7 Thesis Outline

The remainder of the thesis is organized as follows. In Chapter 2, the network audit is introduced. It describes the current, before the work started, data for all the cells of Jawwal GSM network in Jenien city. This includes site example, frequency plan, TRUs configuration, neighbor relations and HSN distributions. Chapter 3 deals with the data collection phase in terms of KPIs. The most common KPIs are defined and their values are then given for Jawwal GSM cells in Jenien city. In chapter 4, the drive test data collected from Jawwal GSM network in Jenien city is listed and analyzed. The optimization work that is conducted manually or with the OSS tools is presented in chapter 5. Chapter 6 contains the comparative study for the performance of GSM network in Jenien city after finishing the enhancement phase. Finally, the conclusions and the suggestions for future work are presented in Chapter 7.

Chapter 2

Jawwal GSM Network Audit in Jenien City

2.1 Introduction

Jenien city[2] is located at the far north of the West Bank in Palestine with current population of 41,646 as reported by the Palestinian Central Bureau of Statistics in 2010. Jenien city is considered a major agricultural center for the surrounding towns [19]. The selection of Jenien city for performing this research is due to the high TCH drop call rate which is about 0.8% and poor quality of service and poor signal strength which is about 8% of the overall collected samples in the drive test that is done in August, 2010.

Table 2.1 shows technical information about the current Jawwal GSM network in Jenien city. These information includes current active sites, serving BSC, serving MSC, BCCH & TCH frequencies and total number of TRUs.

Keep in mind that the sites of Jenien city are named JENIXX, where JENI stands for the RF sites in Jenien city and XX corresponds to two digits site number.

Active Sites in Jenien City	JENI01, JENI02, JENI03, JENI04, JENI05 JENI06, JENI07, JENI08, JENI09, JENI10 JENI11, JENI12, JENI13, JENI14, JENI15 JENI16, JENI17, JENI18, JENI19 and JENI21 and WMIC03.
Total number of sites	21 sites.
Total number of cells	57 cells.
Total number of BCCHs	16 ARFCN.
Total number of TCHs	8 ARFCN.
Total number of TRUs	237 TRUs
Serving BSC	BSC10
Serving MSC	MSC05

Table 2.1: Technical information about current Jawwal GSM network in Jenien city.

Figure 2.1 shows a Google Earth view of Jenien city with the active sites and their geographical locations. Each site consists of two or three cells denoted by cell A, B and C. Where cell A is always the nearest cell to North. Cells B and C are assigned in a clockwise direction.

[2] See the following link: http://en.wikipedia.org/wiki/Jenin

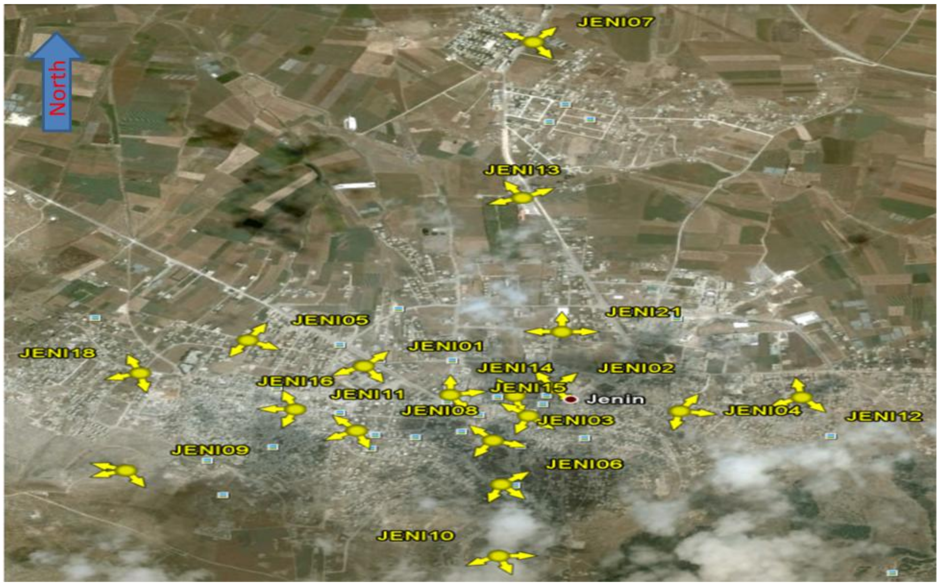


Figure 2.1: Google Earth view of Jenien city with all active sites with their names and direction of the cells.

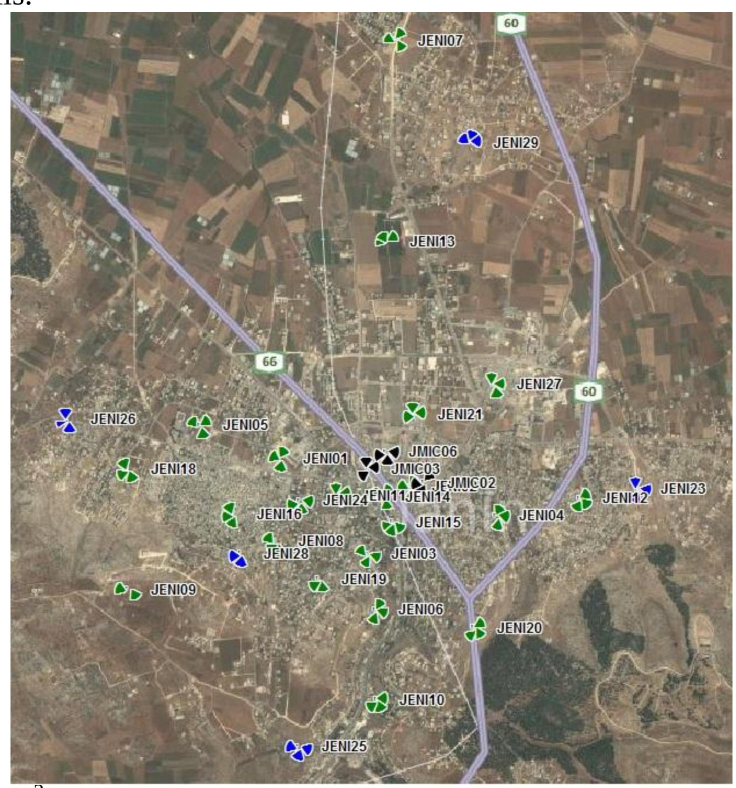


Figure 2.2: PLANET[3] software map that shows all active and planned sites in Jenien city.

Figure 2.2 is a map from PLANET software that illustrates all active and planned sites with cell directions in Jenien city. Note that the active sites are mentioned earlier in Table 2-1, whereas the planned sites are JENI23, JENI24, JENI25, JENI26,JENI27 and JENI29.

[3] PLANET is a professional software tool used as GSM sites database and for coverage predictions. See the following link: www.mentum.com/planet.

2.2 Site Example: JENI11

In this section, an example of an active RF site in Jenien city down town called JENI11 is provided. A general view of the site JENI11 is shown in Figure 2.3 where the objectives of the three cells are illustrated Figure 2.4.

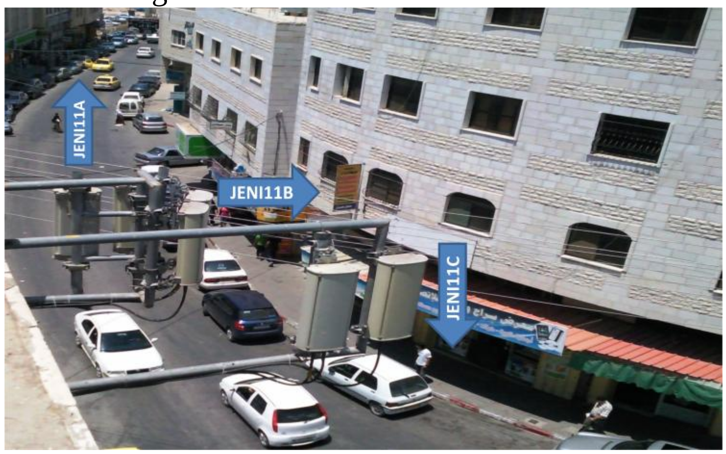
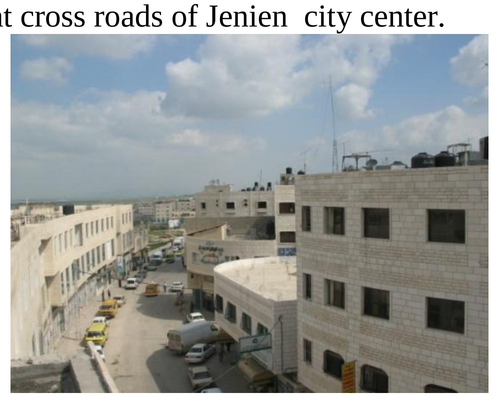


Figure 2.3: General view of the site JENI11 with directions.

Figure 2.4, shows the cell coverage areas for the site JENI11 which consists of cells JENI11A, JENI11B and JENI11C. It should be noted that this site is critical since it covers an urban area at cross roads of Jenien city center.



(a) JENI11A

(b) JENI11B

(c) JENI11C

Figure 2.4: Objective of the cells: (a) JENI11A, (b) JENI11B and (c) JENI11C.

JENI11 is a three sector site with configuration of 3 cells with 6 TRU each. Table 2.3, shows the basic parameter of this site. Where "cell dir" is the azimuth for the cell, "cell type" is the type of the cell Macro or Micro, H is the height of the antenna and antenna tilt is the down or up tilt for the antenna.

Cell I.D	BCCH	BSIC	BSPWRB	BSPWRT	cell dir	cell type	H	antenna tilt	antenna type	antenna gain	HSN	TCHs	TRU
JENI1A	120	26	47	47	0	macro	8	0	sector	13	26	101,104,107, 109,111	6
JENI11B	115	02	41	41	80	macro	8	0	sector	13	26	103,106,110, 112,114	6
JENI11C	117	33	47	47	150	macro	8	0	sector	13	26	105,108,113, 102,116	6

Table 2.2: Parameter of the cells of JENI11.

Table 2.2 shows detailed parameters about the site JENI11. These parameters include the BCCH/BSIC combination for each cell, the power for both the BCCH and TCH carriers, TCH frequencies and the TRU configurations. In addition, other physical parameters for this site are introduced which include the cell direction, height and antenna tilt for each cell.

2.3 Current Frequency Plan For Jawwal GSM Network in Jenien City

There are 124 ARFCN in the GSM900 band. These ARFCN are allocated between the operators such that each operator has its own sub-band to minimize the interference between operators [20]. Jawwal has only 24 ARFCNs which are the last 24 channels in the GSM900 band (i.e., from 101 to 124). These 24 ARFCNs are divided between traffic and control channels. Table 2.3 shows each ARFCN with its UL and DL frequencies. Note that equations (2.1) and (2.2) are used to find the UL and DL frequencies from the ARFCN.

$$\boldsymbol{UL\ Frequency\ (MHz) = 890 + ARFCN * 0.2} \qquad (2.1)$$
$$\boldsymbol{DL\ Frequency\ (MHz) = 935 + ARFCN * 0.2} \qquad (2.2)$$

ARFCN	UL frequency (MHz)	DL frequency (MHz)	ARFCN	UL frequency (MHz)	DL frequency (MHz)
101	910.2	955.2	113	912.6	957.6
102	910.4	955.4	114	912.8	957.8
103	910.6	955.6	115	913	958
104	910.8	955.8	116	913.2	958.2
105	911	956	117	913.4	958.4
106	911.2	956.2	118	913.6	958.6
107	911.4	956.4	119	913.8	958.8
108	911.6	956.6	120	914	959
109	911.8	956.8	121	914.2	959.2
110	912	957	122	914.4	959.4
111	912.2	957.2	123	914.6	959.6
112	912.4	957.4	124	914.8	959.8

Table 2.3: ARFCNs from 101-124 with corresponding UL and DL frequencies.

The frequency plan aims to define the frequencies used by the GSM cells for both control and traffic frequencies. Each cell should have one non-hopping BCCH. This channel is used in downlink only to broadcast cell specific control information to the MS, so the MS always "sees" that channel even though it is the idle state. Also, for each cell a number of traffic channels should be assigned. The number of TCHs in a given cell is related to the number of TRUs as follows:

$$\boldsymbol{TCH = number\ of\ TRUs - 1} \qquad (2.3)$$

2.3.1 Current BCCH plan

A given number of frequencies are assigned to a GSM cell. The coverage of this cell should be limited to an objective area. So, outside this area, the same set of frequencies can be reused in such a way that the capacity of the cellular system will be increased while maintaining acceptable levels of interference [1].
Interference in the control channels (namely BCCH channels) is more critical compared to interference in the traffic channels since it occurs on the channels that are used for performing critical processes such as call setup, handover and mobile registration. Figure 2.5 shows the current BCCH reuse for Jawwal GSM cells in Jenien city.

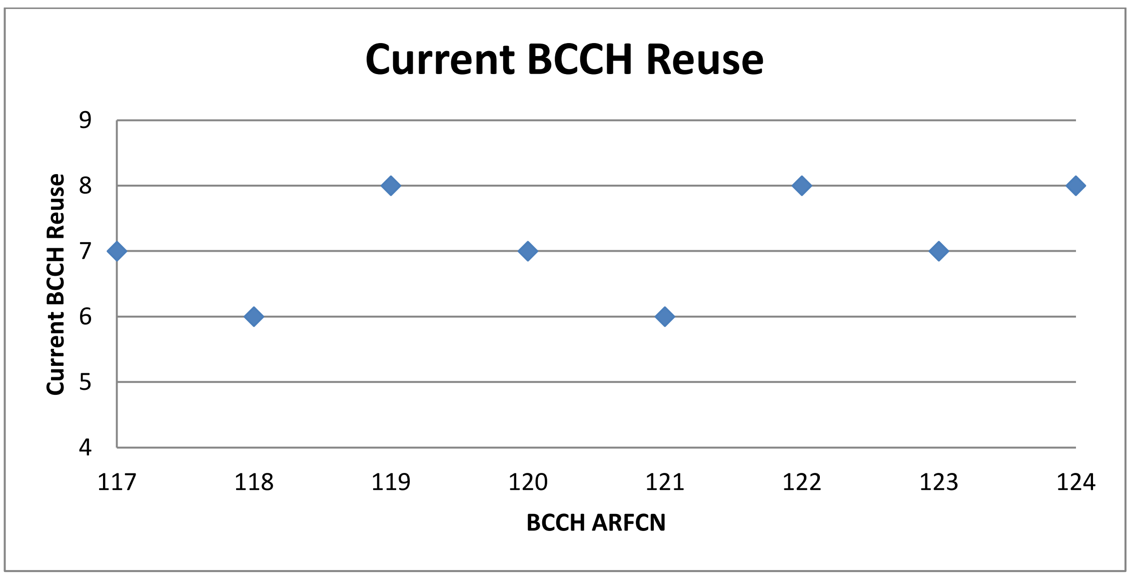


Figure 2.5: Current BCCH reuse plan for Jawwal GSM cells in Jenien city.

From figure 2.5, it is noted that 8 BCCHs are reused between 57 Jawwal GSM cells of Jenien city. This results in very often reuse for a given BCCH. As an example you can note that the BCCH 124 is reused 8 times, this means that we have 8 cells in Jenien city with 124 as their serving BCCH. The above situation results in high level of interference on the BCCH carrier which results in poor QoS and high drop rate for those cells. To avoid this problem, one can increase the number of BCCH channels. However, due to the limited number of channels available to Jawwal (24 channel), it comes at the cost of reducing traffic channels. A more tight frequency plan and balance between the TCH and BCCH in Jenien city will be proposed later in chapter 5.

2.3.2 Current TRUs configuration and TCH plan

Table 2.4, shows the current TRU configuration for each cell in Jawwal GSM network in Jenien city.

Cell I.D	Current TRUs	Cell I.D	Current TRUs	Cell I.D	Current TRUs	Cell I.D	Current TRUs
JENI01A	8	JENI06A	4	JENI11B	6	JENI16C	4
JENI01B	4	JENI06B	4	JENI11C	6	JENI17A	2
JENI01C	6	JENI06C	4	JENI12A	4	JENI17B	4
JENI02A	6	JENI07A	4	JENI12B	4	JENI18A	4
JENI02B	4	JENI07B	4	JENI12C	4	JENI18B	4
JENI02C	6	JENI07C	4	JENI13A	4	JENI18C	4
JENI03A	4	JENI08A	4	JENI13C	4	JENI19A	4
JENI03B	4	JENI08B	4	JENI14A	4	JENI19B	2
JENI03C	4	JENI08C	4	JENI14B	4	JENI21A	4
JENI04A	4	JENI09A	4	JENI14C	4	JENI21B	4
JENI04B	4	JENI09B	2	JENI15A	2	JENI21C	4
JENI04C	4	JENI10A	4	JENI15B	2	WMIC03A	4
JENI05A	4	JENI10B	4	JENI15C	8		
JENI05B	3	JENI10C	4	JENI16A	4		
JENI05C	4	JENI11A	6	JENI16B	4		

Table 2.4: Current TRU configuration for Jawwal GSM network in Jenien city.

From table 2.4 and equation 2.3, we can find the number of traffic channels for each cell. Take an example of JENI 11 again. JENI11A is configured with 6 TRUs resulting in 5 TCH from equation 2.3. Another 5 TCHs for JENI11B and another 5 TCHs for JENI11C. Thus, 15 TCHs must be reserved for traffic. As safety margin and in case of the traffic is increased 16 ARFCNs are assigned for traffic. This is also valid for the site JENI01. So, 16 TCHs are used for traffic, which leaves only 8 for control (24-16)=8.

Figure 2.6, shows the current traffic channel frequency reuse pattern for Jawwal GSM network in Jenien city.

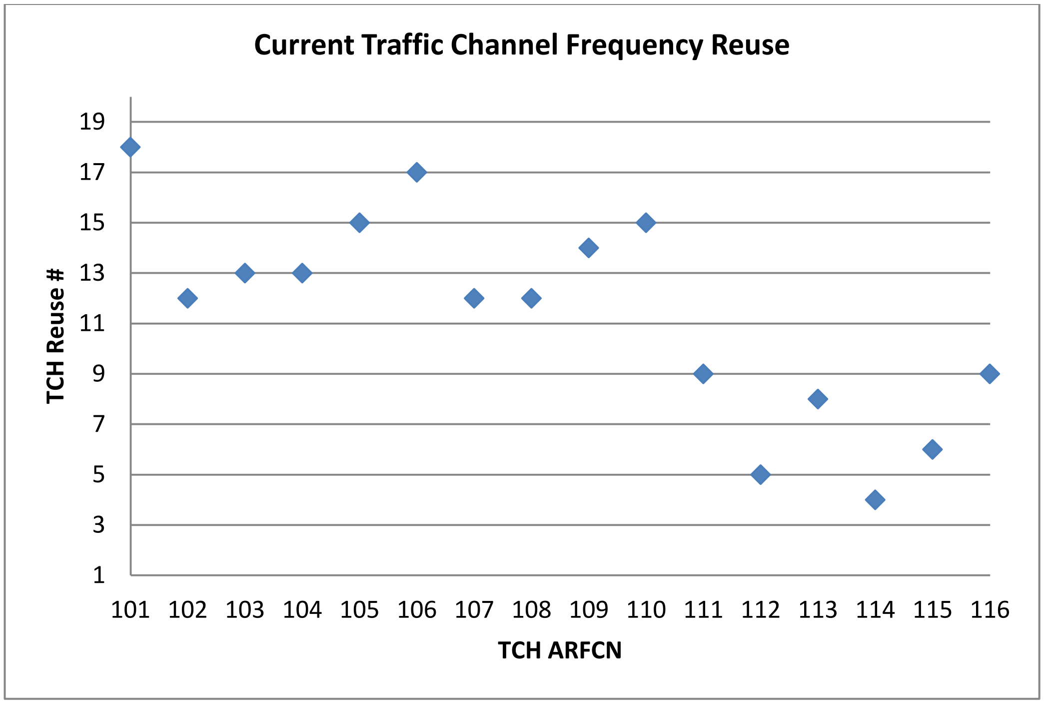


Figure 2.6: Current TCH frequency reuse plan for Jawwal GSM cells in Jenien city

Note that the traffic channels are reused very often which results in interference on the traffic channels. Nevertheless, this interference can be minimized since frequency hopping is activated for the traffic frequencies. However, the BCCH is a non-hopping channel, because of the continuous nature of transmitting for the BCCH so MS can camp on instantly. This leads us to HSN planning which is the topic of the next section.

2.3.3 Current HSN distribution

HSN is a very important concept used to minimize the interference on the traffic channels. It is very important to note that close sites must have different HSN. As HSN have range from 0 to 63, it is recommended that in a small city like Jenien to assign each site a different HSN [21].

Site I.D	Current HSN	Site I.D	Current HSN	Site I.D	Current HSN
JENI01	1	JENI08	31	JENI15	9
JENI02	35	JENI09	22	JENI16	12
JENI03	7	JENI10	19	JENI17	37
JENI04	10	JENI11	26	JENI18	54
JENI05	43	JENI12	40	JENI19	50
JENI06	40	JENI13	61	JENI21	18
JENI07	45	JENI14	55	WMIC03A	30

Table 2.5: Current HSN for Jawwal GSM sites in Jenien city.

From table 2.5, it is noted that JENI06 and JENI12 have the same value of HSN=40. Thus, the HSN value for one site should be changed, to minimize the interference on the TCH frequencies.

2.3.4 Current neighbor relation plan

Neighbor relations are essential when considering MS handover from one cell to another to maintain good QoS. The current neighbor relation plan is constructed depending on the geographical locations of the cells and on suggested mobility profile.

It is recommended to have neighbor relations of each cell between 6 to 15 cells. But, there are of course special cases that this rule will be violated. Fewer neighbor relations mean that there will be dropped calls because of the missing neighbor relations. On the other hand, too much neighbors results in additional load on the BSC and MS at the handover attempt [21]. Figure 2.7, shows the current number of neighbor relations that are defined for each cell in Jenien city.

The average of number of neighbors is about 18 neighbor per cell and this is a good average. It is noted from Figure 2.7 that cell JENI09B has very high neighbor relations (36 neighbors). About 59.6% of the cells have more than 15 neighbor relations.

In chapter 5 of this thesis a detailed neighbor relation scan will be made, applied and then tested to minimize TCH drop rate and improve QoS.

2.4 Conclusion

This chapter aims to audit the current Jawwal GSM network deployed in Jenien city. The audit is conducted in terms of active and planned sites, frequency plan, HSN and neighbor relations.

Firstly, the active and planned sites are presented. JENI11 is taken as an example. Secondly, detailed parameter audit is executed which consists of mainly the current frequency plan for both traffic and control frequencies. The BCCH reuse pattern is then introduced where it is noted that 8 BCCHs are reused between all the cells of Jenien city. TRU configurations are then listed and are related to the number of traffic channels. Thus, the 24 channels available to Jawwal are divided into 16 TCHs and 8 BCCHs. Finally, a detailed neighbor relations plan is presented.

In the next two chapters, two methods that are used to evaluate and enhance the performance of the Jawwal GSM network in Jenien city are presented. These two methods are KPIs and drive tests.

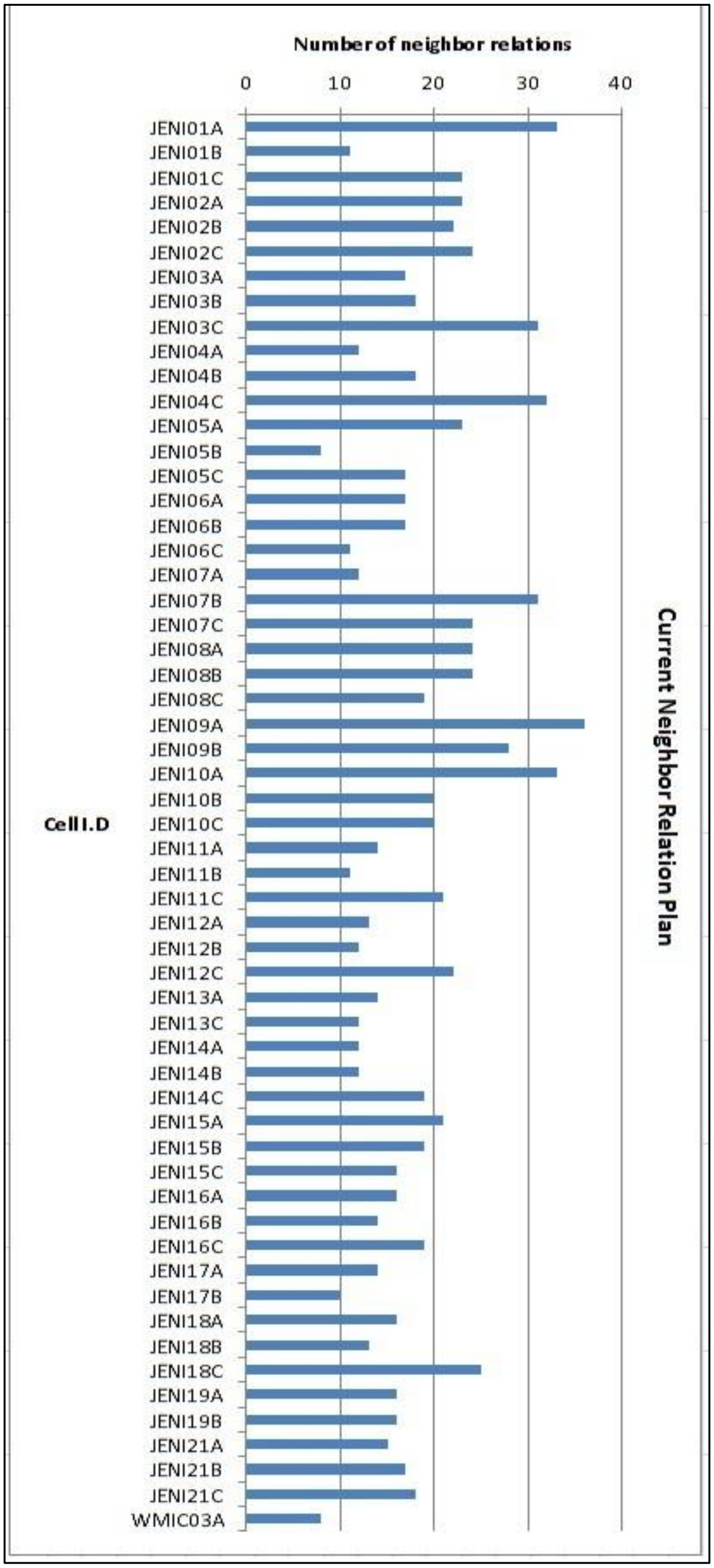


Figure 2.7: Current neighbor relations for the cells in Jenien city.

Chapter 3

Key Performance Indicators (KPIs)

3.1 Introduction

KPIs are used to evaluate the performance of an operating GSM network. These KPIs come from the OSS in form of counters. These counters are then converted into a more readable way [11]. The most common KPIs are listed below [5] [6] [7] [8] and [12].

a. TCH drop rate: This is one of the most critical KPIs in GSM networks since it is annoying to the customer and the operator. It is the percentage of lost connections to the total number of connections for a given cell in the active mode (on call). This KPI ranges from 2% in the initial launching for the cell and it must be decreased to 0.5% in normal operating conditions.
b. SDCCH drop rate: It is the percentage of the lost SDCCH connections to the total SDCCH connection attempts. Keeping in mind that the SDCCH is used during vital roles such as call setups and mobile registration.
c. TCH congestion and congestion perceived by subscriber: There are two different approaches when dealing with TCH congestion. The TCH congestion perceived by subscriber is more realistic since it is from user's point of view rather than the congestion observed by the network and it is given by TCH congestion. The last one is from network's point of view.
d. TCH assignment success rate: It is a measure of the successful TCH assignments to the total attempts. It is recommended to keep this value as close to 100% (typical value is 99.7%).
e. Handover success rate: It is the percentage of successful handovers to the total number of handover attempts. The high handover success rate gives an indication to the good neighbor relation plan in the network.
f. SDCCH congestion: SDCCH is used during call setup, mobile registration and SMS. The SDCCH congestion is the percentage of the time that all SDCCH resources are busy within a given cell. The accepted value is no more than 0.5.

The KPIs provide comprehensive data about the cell behavior in both UL and DL. These data can be obtained without the need for extra measurements. Nevertheless, a specialized knowledge is needed to retrieve the data from the OSS [22]. At the starting stages of this research work, the KPIs are taken in Jenien city from November, 1st till November, 26th in 2010.

3.2 TCH Drop Rate

TCH drop rate is one of the most critical KPIs for both customer and GSM operator. TCH drop rate is the KPI that gives us the percentage of dropped connections during the connection mode to the total connections accessed by that cell.
Figure 3.1, shows the behavior of TCH drop rate for Jenien city cell set during 01 to 26 of November, 2010.

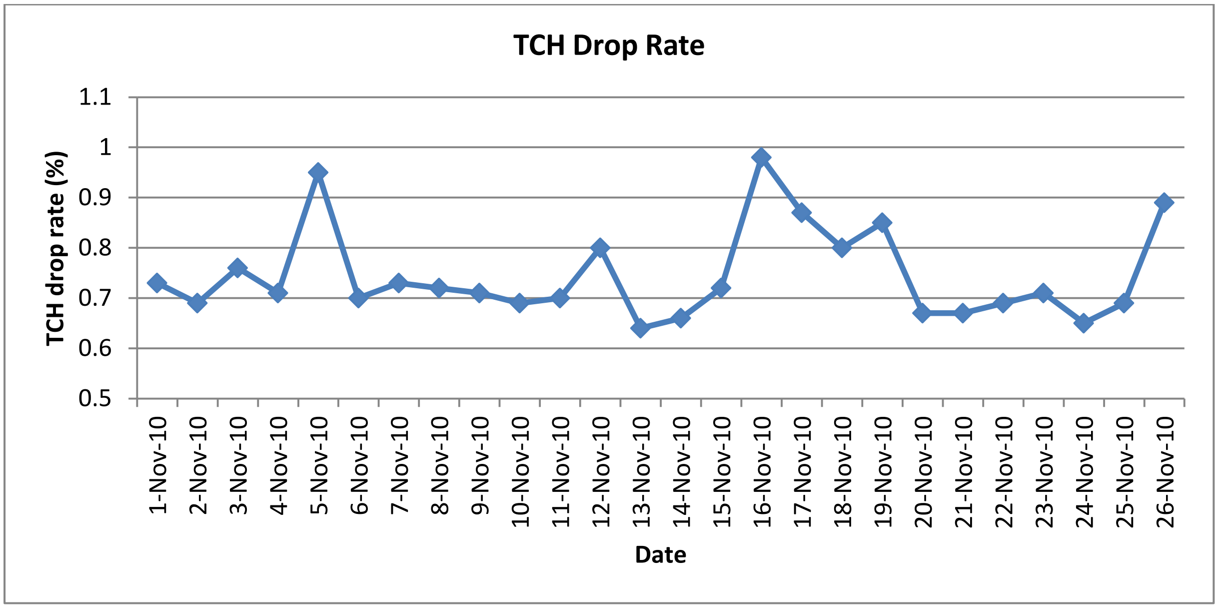


Figure 3.1: TCH drop rate for Jenien city cell set in November, 2010.

Figure 3.1 shows that the drop rate for Jenien city cell set varies from 0.65% to nearly 1% in the given period, the TCH drop rate equals 0.745% in average during that period. The OSS provides not only the drop rate for a given cell, but also it indicates the possible reason for the drop rate with the percentage of each reason. The TCH drop rate reasons are explained in the next sections.

3.2.1 TCH Drop due to Quality (TD_Q)

The TCH Drop rate due to Quality is the dominant reason for TCH drop in Jenien city cell set which is related to poor quality (high interference). The C/I and C/A on both control and traffic channels is the issue here. To overcome this kind of drop, the existing control and traffic frequencies must be reused efficiently, using features such as frequency hopping or even using new frequencies. The drop due to quality is classified into:

1. TCH Drop rate due to Quality in the DL (TD_QDL):
   Here C/I on the control channels in the DL, mainly the BCCH, is the direct reason for this drop. The solution is to use more tight BCCH frequency plan in which less C/I level exists for each BCCH carrier.

2. TCH Drop due to Quality in the UL (TD_QUL):
   Here the poor quality in the uplink causes TD_QUL to occur. This is due the interference on the UL direction caused by the C/I and C/A at the frequency that the MS transmits.

3. TCH Drop due to Quality in Both Links (TD_QBL):
   This is the drop caused by both TCH_QUL and TCH_QDL. This means that this TCH drop occurs when there is poor quality (high interference) in both directions UL and DL.

3.2.2 TCH Drop due to Signal Strength (TD_SS)

The TCH Drop due to Signal Strength is caused by the weak signal from either the BTS side, or MS side or both. The drop due to signal strength is classified into:

1. TCH Drop rate due to Signal Strength in the UL (TD_SSUL):
   This type of drop is due the weak signal strength of the MS. This means that the MS is not able of sending more power to the BTS so the communication is lost. There are special solutions that include the use of additional hardware to cure this kind of drop.

2. TCH Drop rate due to Signal Strength in the DL (TD_SSDL):
   TCH_SSDL is the drop on the TCH due to signal strength in the DL. This means that the BTS is away from the MS. So, it could not transmit sufficient power to maintain that connection. This will be enhanced by activating the new planned sites in Jenien city which will reduce this drop reason.

3. TCH Drop rate due to Signal Strength Both Links (TD_SSBL):
   TCH_SSBL is the drop that occurs when both the MS and BTS are not able of sending more power to maintain the connection between them. This drop gives us an indication about poor coverage areas and the need for activating new sites.

3.2.3 TCH Drop due Suddenly lost connection (TD_SUD)

The TCH Drop due to Suddenly lost connection (TD_SUD) is caused by losing the call suddenly, which is mostly related to transmission between the BTS and BSC. This drop can be lowered by maintaining good quality of the transmission medium between all the BTSs and their BSC.

3.2.4 TCH Drop due to Time Advance (TD_TA)

The Time Advance (TA) is expressed as the distance from which the traffic comes. Here we can estimate the cell radius and know if the cell is serving its primary objective or it is overshooting further more. TCH Drop due to TA or TD_TA means that traffic is dropped when TA exceeds a user defined limit. This limit is defined to maintain good QoS when connecting to a nearby cell.

3.2.5 TCH Drop due to Others (TD_Others)

The TCH Drop due to Others (TD_Others) is about the non-radio reasons in the GSM network. These are commonly related to the hardware of the BTS, BSC or both. When a call is dropped for any other reasons than the mentioned earlier, the TD_Others counter is incremented.

The percentage of each TCH drop rate reason for Jawwal GSM network is given in figure 3.2.

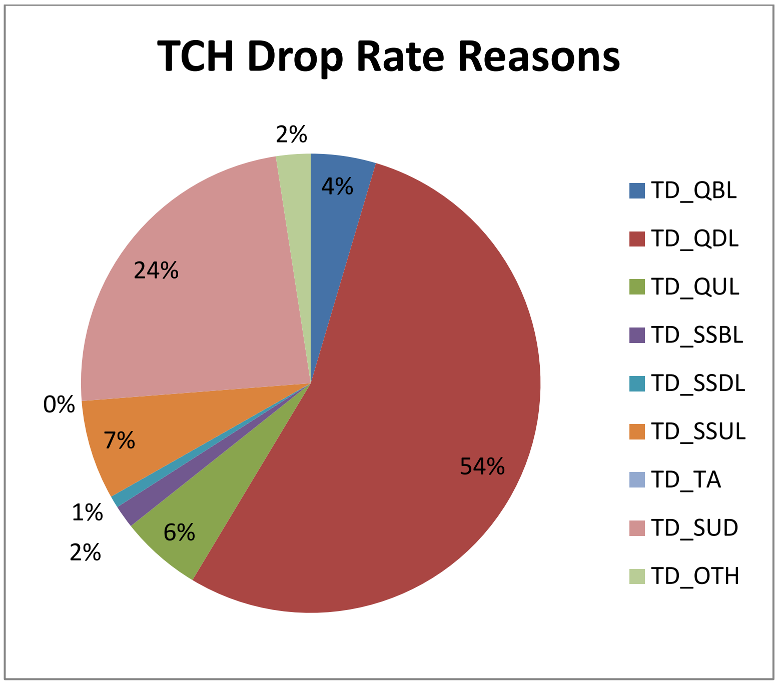


Figure 3.2: TCH drop reasons for Jenien city cell set in November, 2010.

According to figure 3.2 the TD_QDL is the dominant drop reason for the traffic drop. This high percentage of TD_QDL means that there is interference on the BCCH carrier in the DL direction. The next reason for traffic drop rate is the TD_SUD which means fluctuations of the quality of the transmission medium between the BTS and BSC. The TD_SS is another reason for TCH dropped calls.

3.3 SDCCH Drop Rate and SDCCH Congestion

The KPIs for control channels are critical because these control channels are used in vital roles such as call setup, mobile registration, etc. Also because of the continuous transmission on the control channels. SDCCH drop rate shows the drop rate for these control channel. SDCCH congestion is the KPI that measures the congestion on the SDCCH. The behavior of these two KPIs is shown in the Figure 3.3 from November, 1st to November, 26th 2010.

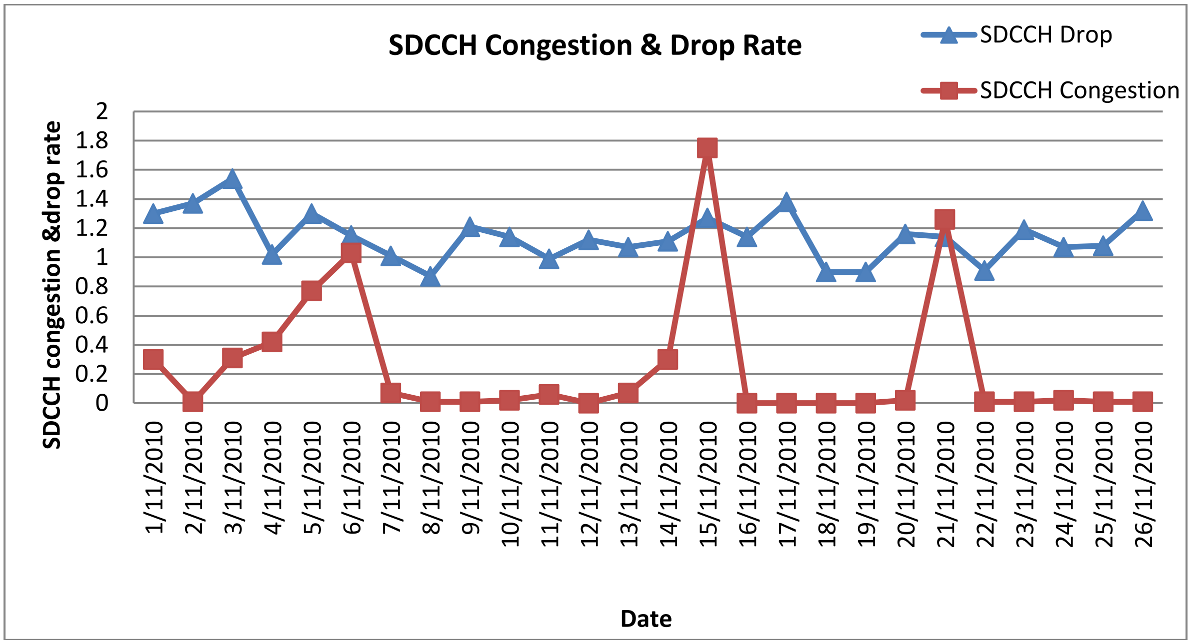


Figure 3.3: SDCCH drop rate and SDCCH congestion for Jenien city cell set in November, 2010.

SDCCH congestion is another important KPI that measures the congestion on the SDCCH resources. The SDCCH resources are dimensioned as in the traffic channels using the Erlang B tables.

The reasons that are responsible for SDCCH drop rate are listed as follows. It is noted that these reasons are similar to those of TCH drop rate.

3.3.1 SDCCH drop due to quality

SDCCH drop due to Quality (SDCCH_drop_Q) is caused by the interference which affects the SDCCH carrier frequency.

3.3.2 SDCCH drop due to signal strength

SDCCH drop which happens due to Signal Strength (SDCCH_drop_SS) is a result of the weak signal strength between the MS and BTS.

3.3.3 SDCCH drop due to TCH congestion

SDCCH can be caused by the congestion on the TCH (SDCCH_drop_TCH congestion). The SDCCH are used for call setups. In the case of TCH congestion, it is recommended that the existing user still be connected to the network while blocking other users trying to setup new calls. In that case, the SDCCH drop due to TCH congestion counter will be incremented.

3.3.4 SDCCH drop due to time advance

The SDCCH drop due to Time Advance (SDCCH_drop_TA) is the drop on SDCCH when the call is being established from a distance more than the TA.

3.3.5 SDCCH drop due to others

SDCCH drop due to Others (SDCCH_drop_Others) is non-radio reason that makes SDCCH connections to be dropped. This reason includes hardware faults of the BTS and BSC. The cells of high drop rate due to others are monitored and reported to check the hardware of the site.

The percentage of each reasons of SDCCH drop is illustrated in figure 3.4 .

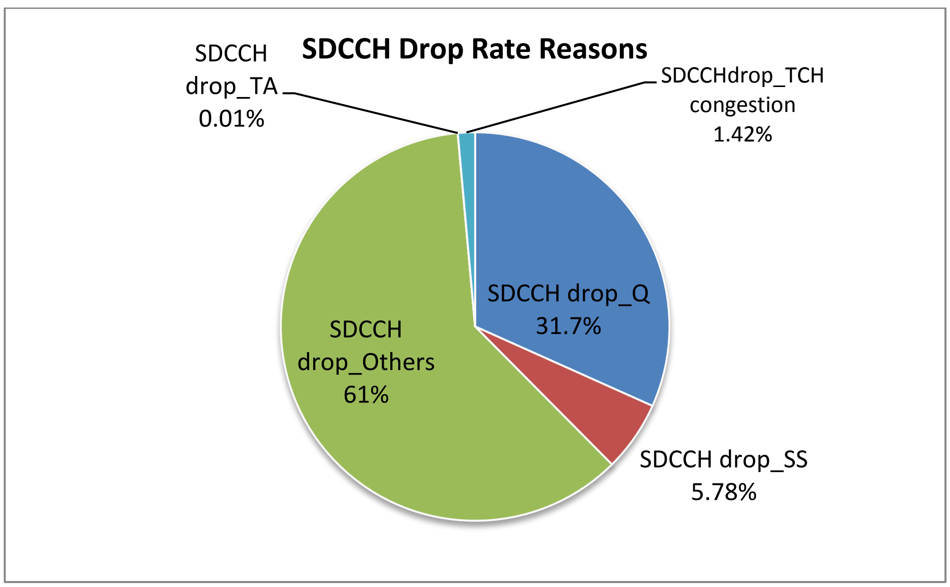


Figure 3.4: SDCCH drop reasons for Jenien city cell set in November, 2010.

It is noted from Figure 3.4 that the main reason for SDCCH drop rate in Jenien city is due to others with 61% of the overall SDCCH drop. Jawwal is working on this SDCCH drop_Others issue in order to enhance the performance of the overall network so as to lower this percentage. The SDCCH_drop_Quality is the second reason in the list with 31.7%. It is due to the interference on the BCCH channels. The percentage of SDCCH drop due to signal strength is 5.78%. This is because the cell is the dominant in a relatively large geographical area. So the SDCCH drop is made due to weak signal strength and lack of a servers. This will be solved when activating the new planned sites. SDCCH drop due to congestion is with small percent. The solution is to increase the capacity of the affected cells which can be done after checking the TCH congestion. SDCCH drop due to TA yields the lowest percentage with 0.01%.

3.4 TCH Congestion and subscriber perceived TCH congestion

The traffic congestion is an important KPI which reflects a bad cell design from the capacity point of view. Here, two KPIs are used to address the same issue which is traffic congestion. The first is the traffic congestion which shows how much the channel resources are busy according to the channel available resources. The second is the subscriber perceived traffic congestion which gives indication of how much the subscriber tries to access the network and gets no traffic assignment due to busy resources. We give more care to the second KPIs since it reflects the actual subscriber's point of view.

Figure 3.5 shows the cells that suffers from TCH congestion, subscriber perceived TCH congestion or both. It is noted that the cell JENI14C is on the top of the list in terms of TCH congestion. This cell is located in Jenien city center and therefore it suffers from high TCH congestion. To solve this problem, a new site can be placed within that area to share the traffic and reduce congestion.

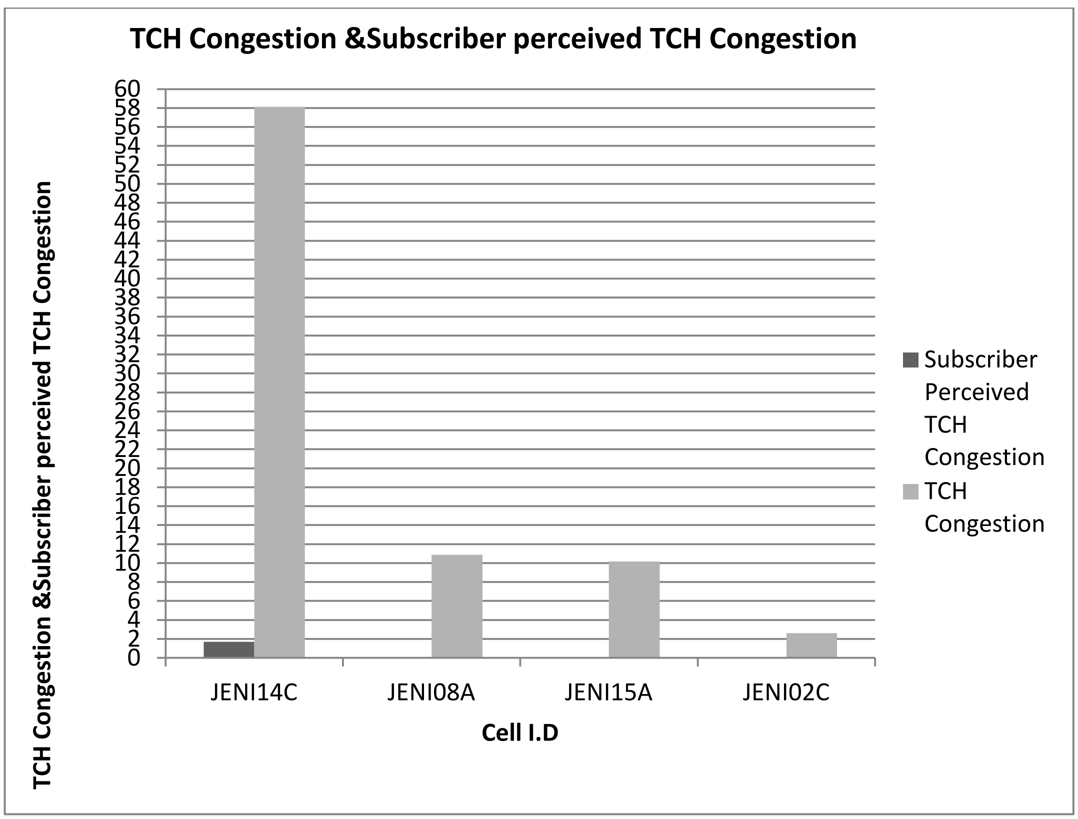


Figure 3.5: Some cells in Jenien city with TCH congestion and subscriber perceived TCH congestion or both during November, 2010.

3.5 TCH Assignment Rate

TCH assignment rate is the rate of assignment of a TCH to a user who is requesting that channel. Figure 3.6 shows the percentage of TCH assignment rate for all GSM cells in Jenien city. The threshold of this KPI is 99.7%.

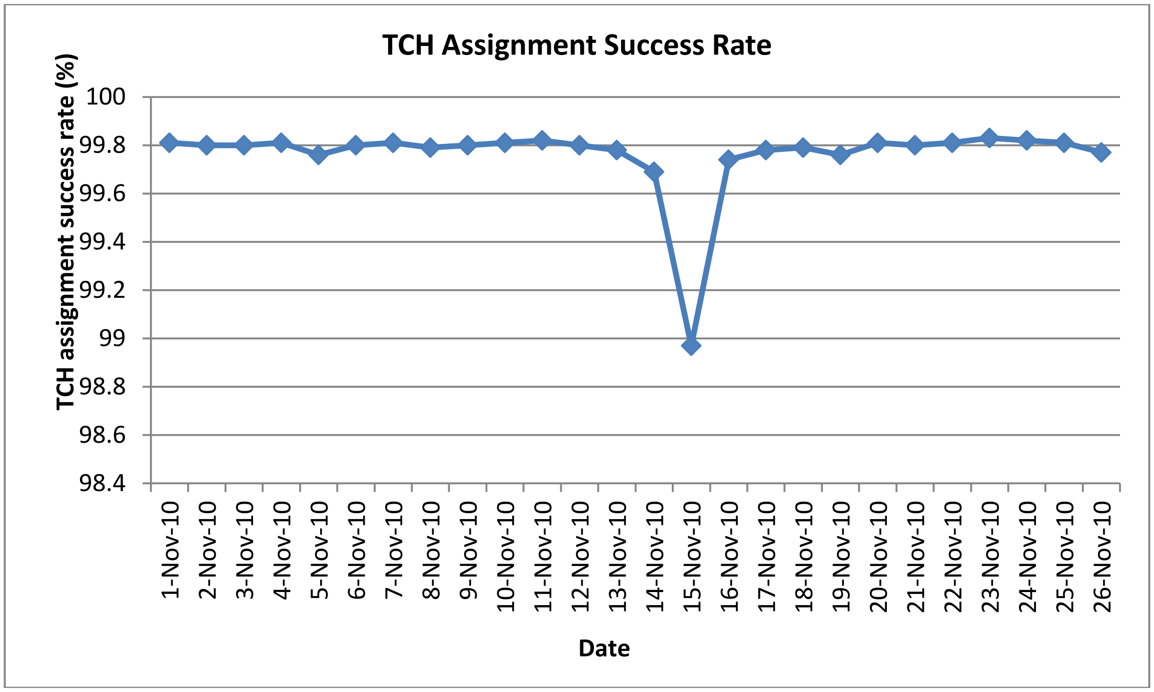


Figure 3.6: TCH assignment success rate for Jenien city cell set in November, 2010.

From Figure 3.6, it is noted that the TCH assignment rate is above 99% for all the period except the day of November 15th. This may be due to unusual event at that period or it may be due to problem in one of the sites in Jenien city. However, the average of the TCH assignment rate for the overall period equals 99.76% which is still above the threshold.

3.6 Handover Success Rate

Handover is an essential process in which the MS is handed over from the serving cell to its neighbor cell to maintain the required QoS. Consider the following example in which the serving cell is JENI01A and during the call the MS moves from JENI01A towards JENI05A. The success handover is made when the call is transferred from the cell (JENI01A) to its neighbor cell (JENI05A) without disconnection. In our example, it is considered as outgoing handover for the cell JENI01A and incoming handover for the cell JENI05A.
The overall handover success rate for Jenien city cell set in November, 2010 is shown in figure 3.7.

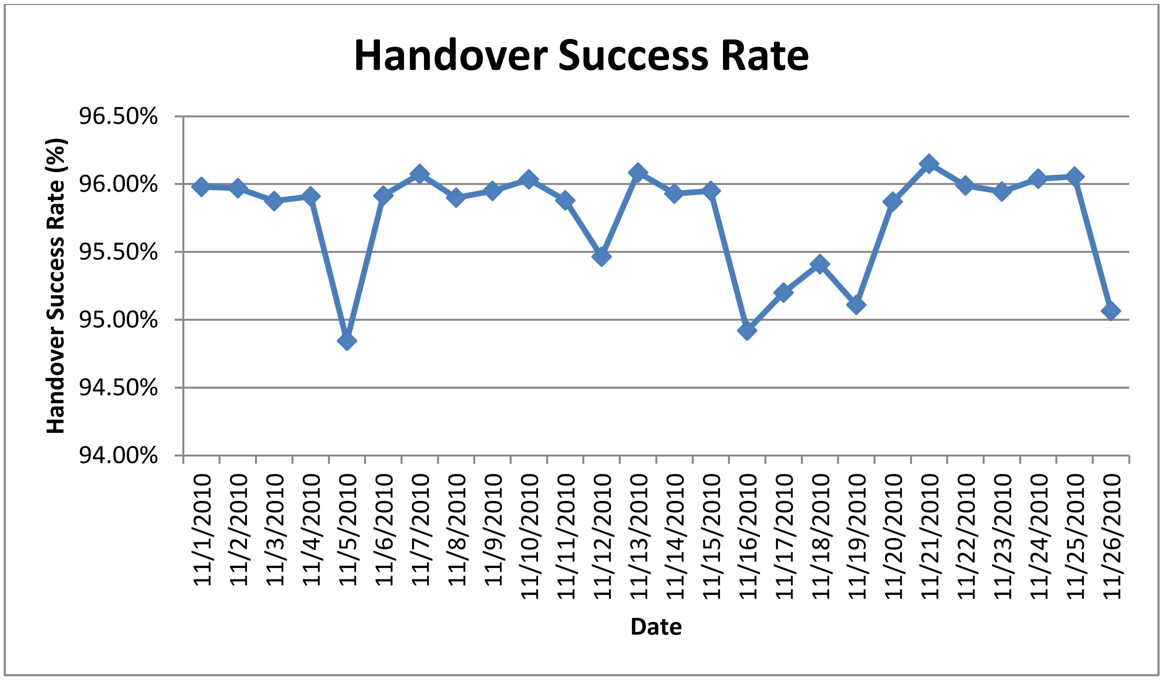


Figure 3.7: Handover success rate for Jenien city cell set in November, 2010.

From Figure 3.7, the average of the handover success rate for Jenien city cell set is calculated to be 95.75%which is considered as a good handover performance. Keep in mind that the handover is very much related to the neighbor relation plan which will be investigated further.

After presenting the major KPIs for all Jawwal GSM cells in Jenien city, it is now worth to present the worst performing cells in terms of each KPI. This will give indication of the worst cells that heavily impact the overall performance. Also, these worst performing cells are used to highlight the main issues in Jawwal GSM network in Jenien city.

3.7 Worst Performing Cells

The worst performing cells of each KPI are presented with the reasons that made that cell on the top list of that given KPI. The idea here is to find a solution for those cells, so as to improve the overall performance for Jawwal network in Jenien city.

1. TCH drop rate worst performing cells:

As we discussed earlier, the threshold for drop rate is 0.5%, so the cells that have more that 0.5% TCH drop rate will be considered as worst performing cells. Figure 3.8 shows the top 10 worst performing cells in terms of TCH drop rate in Jenien city during November, 2010.

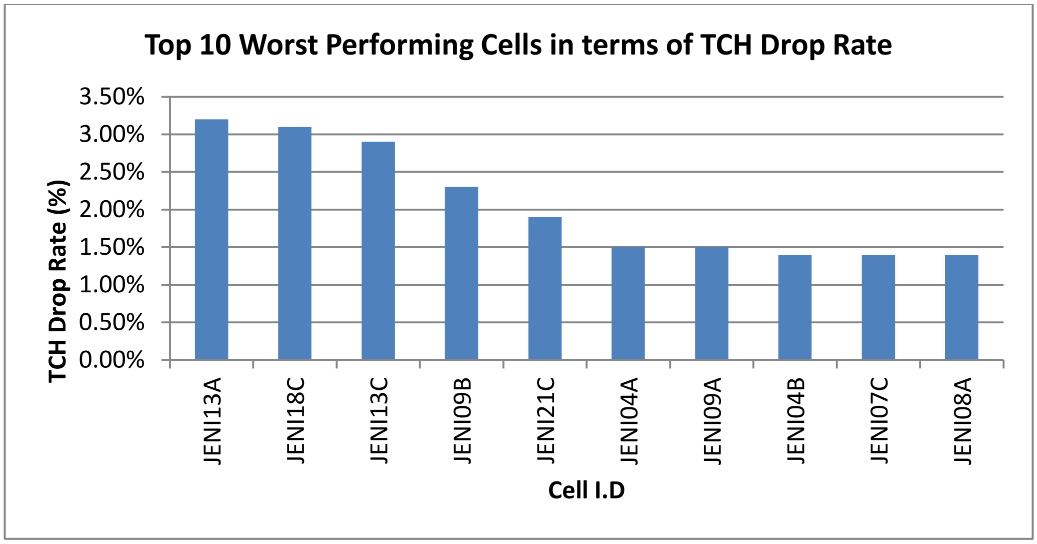


Figure 3.8: Top 10 worst performing cells in terms of TCH drop rate in Jenien city in November, 2010.

It is noted that JENI13A is on the top of the cells in TCH drop rate with percentage of 3.20%. So, it is required to find the main reason for the high TCH drop rate for this cell. These reasons are explained in Figure 3.9.

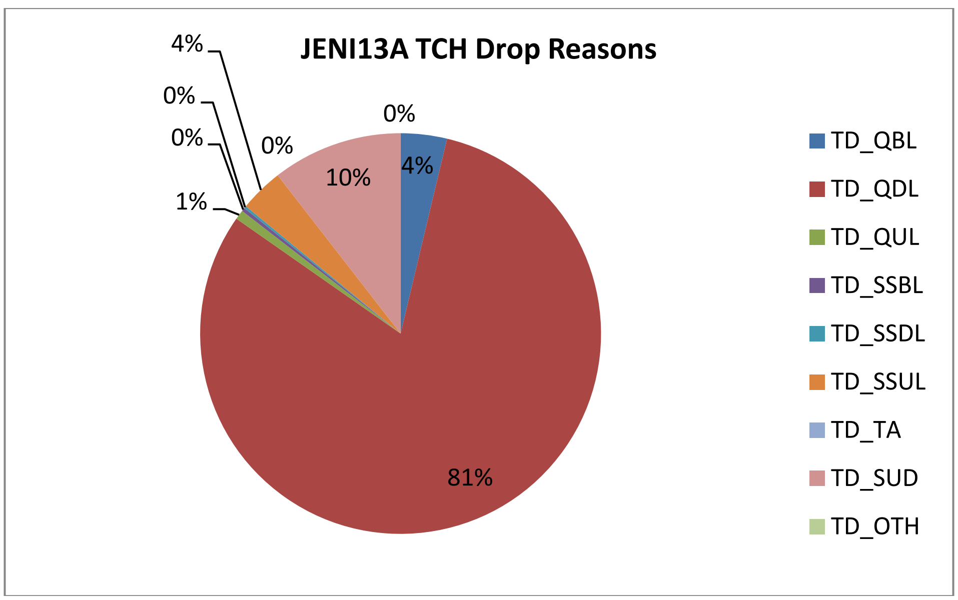


Figure 3.9: JENI13A TCH drop rate reasons.

JENI13A is ranked as number one in terms of TCH drop rate. With the TD_QDL as the main reason for that high TCH drop rate. More specifically, the TD_QDL is with 81% of the overall TCH drop. This is translated to high level of interference on the BCCH carrier in the DL direction.

2. SDCCH drop worst performing cells:

The top 10 worst performing cells in terms of the SDCCH drop rate in Jenien city are shown in Figure 3.10. The cell JENI06B is the worst cell with more than 2.5% drop in SDCCH.

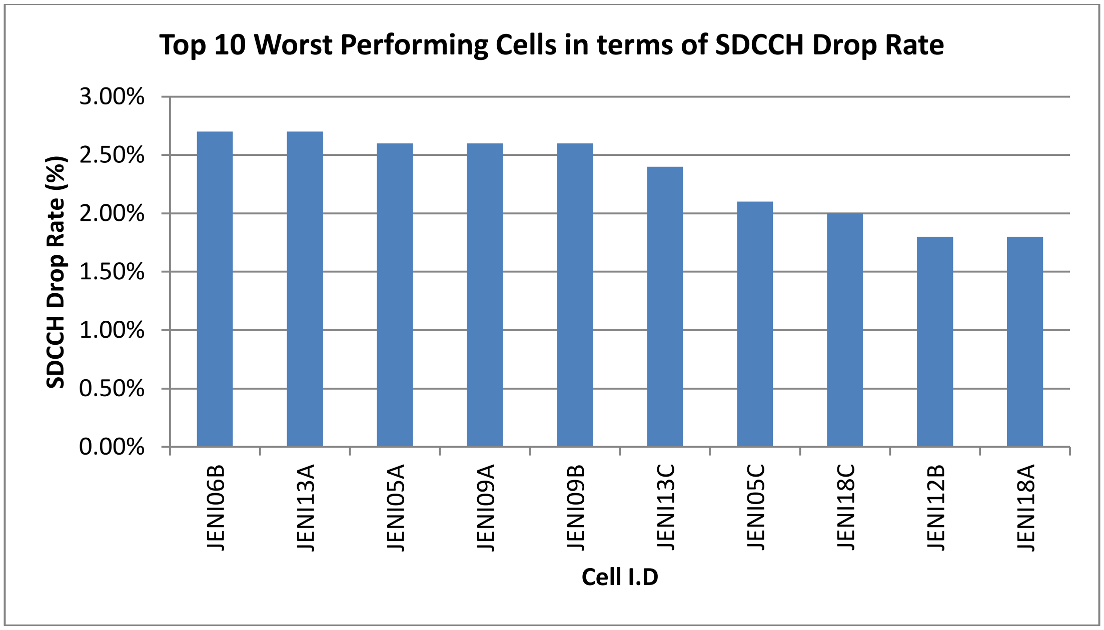


Figure 3.10: Top 10 worst performing cells in terms of SDCCH drop rate in Jenien city during November, 2010.

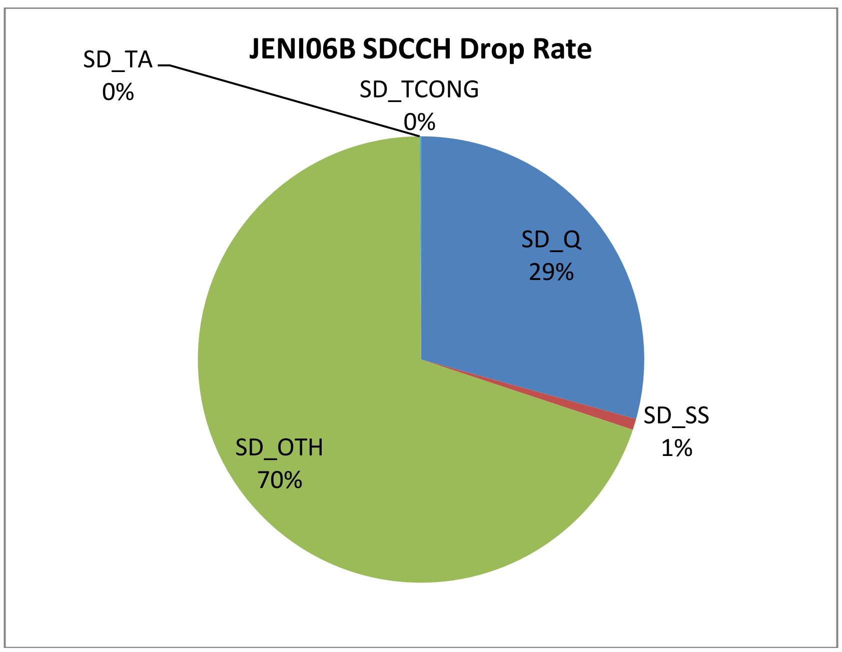


Figure 3.11: SDCCH drop rate reasons for the worst performing cell JENI06B.

From Figure 3.11, it is noted that the high SDCCH drop rate on the cell JENI06B is due to others reason, with 70%.

3. TCH congestion and subscriber perceived TCH congestion worst performing cells:

Figure 3.12 shows the worst performing cells in terms of TCH congestion and subscriber perceived TCH congestion for Jenien city cell set during November, 2010.

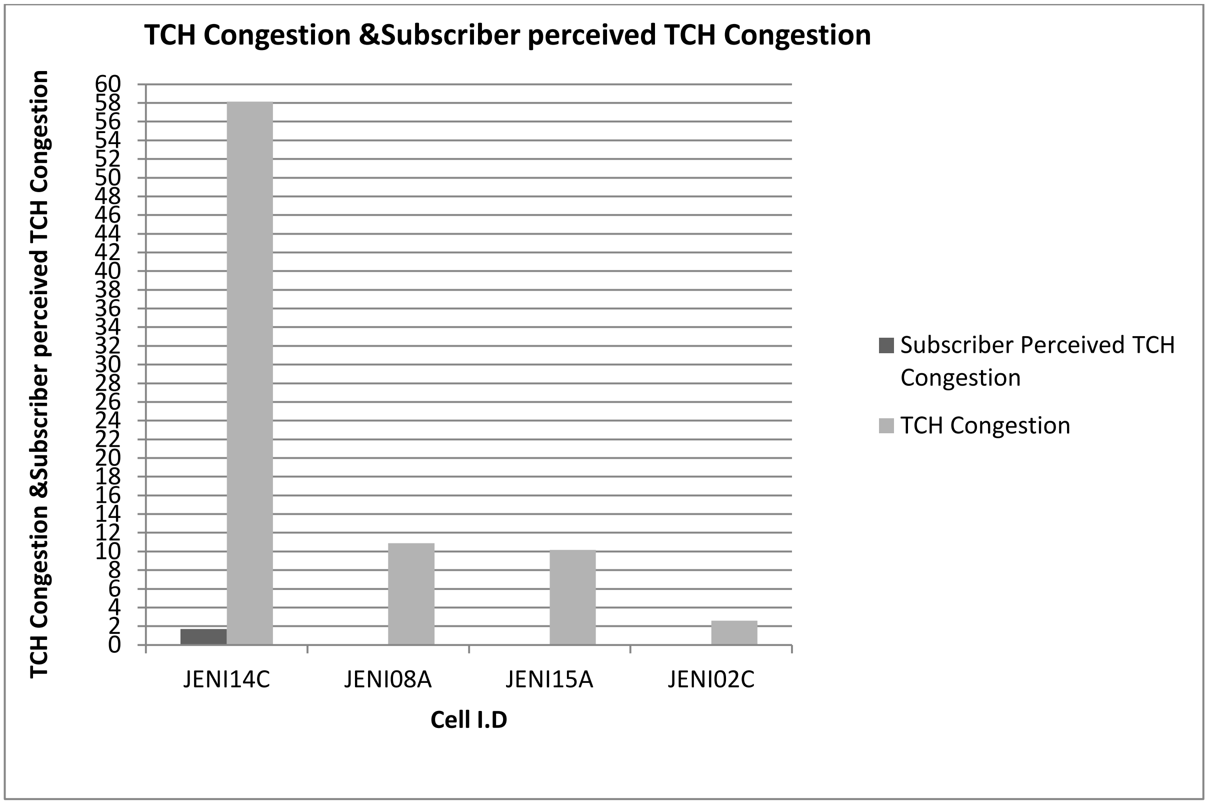


Figure 3.12: Worst performing cells in terms of TCH congestion and subscriber perceived TCH congestion for Jenien city cell set during November, 2010.

It is noted that the cell JENI14C is the only cell with high TCH congestion and with a little bit subscriber perceived TCH congestion. It is worth here to remind that the KPIs of subscriber perceived TCH congestion give more realistic reading for this KPI. This cell is located in the Jenien city center which is a dense urban area. The solution here is to implement new sites to serve that same area. So, traffic can be shared among these cells. The issue of congestion will be exposed in chapter 5 when we present capacity analysis for Jenien city cells.

4. TCH assignment success rate worst performing cells:

The worst cells in terms of TCH assignment rate are the cells with TCH assignment success rate less than the threshold of 99.7% in Jenien city.

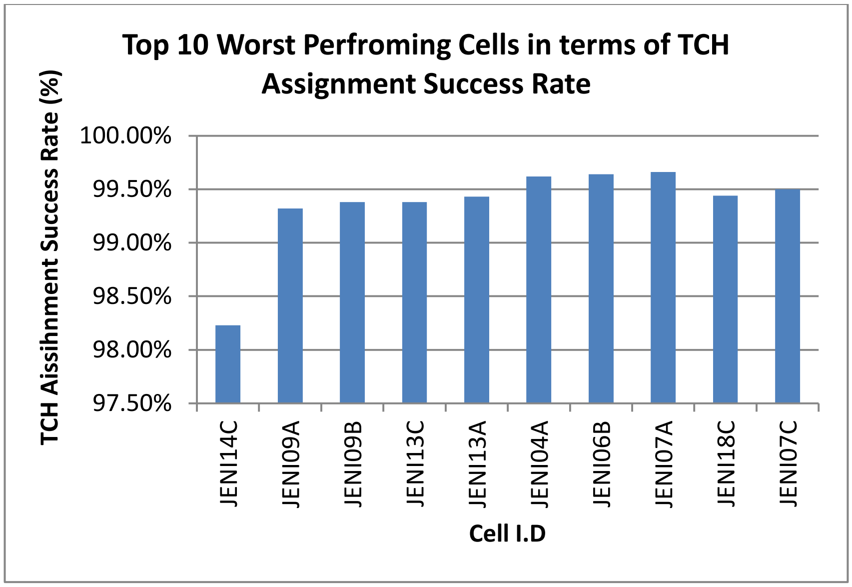


Figure 3.13: Top 10 worst performing cells in terms of TCH assignment success rate for Jenien city cell set in November, 2010.

Again the cell JENI14C is the worst cell in terms of TCH assignment success rate. This is a direct result of TCH congestion on that cell. Since the cell JENI14C is congested, any user tries to access that cell will be blocked because there is no available resources. This is the reason behind poor TCH assignment success rate for that cell.

5. Handover success rate worst performing cells:

The handover success rate top 10 worst performing cells in Jenien city are presented in figure 3.14. From which, it is noted that the worst cells are also JENI13A and JENI13C which are also on the top of the traffic drop worst performing cells.

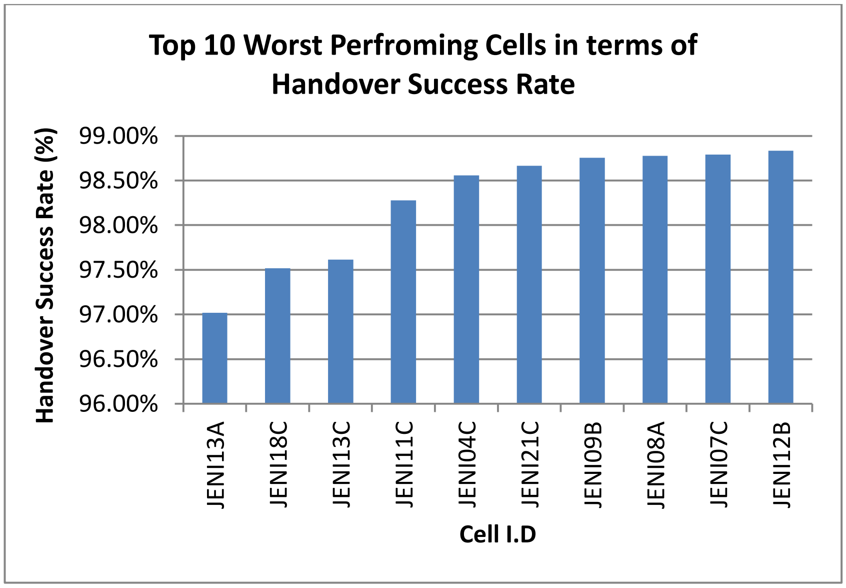


Figure 3.14: Worst performing cell in terms of handover success rate.

JENI13A and JENI13C are the worst performing cells in terms of handover success rate. This is a direct result of the TD_QDL. These cells suffer from high interference on the BCCH which makes them loose the incoming handovers from other cells. Also this is the reason for high TCH drop rate.

3.8 Conclusion

KPIs provide a comprehensive view and very efficient tool for evaluating the performance of alive GSM network. In this research, the most common KPIs are investigated to evaluate the GSM network in Jenien city. These KPIs are presented, listed, and evaluated for all GSM cells in Jenien city. The performance of each KPI is presented and the reasons behind their behavior are clarified. For cells with poor performance in any given KPI, the reason is investigated and in some cases solutions are proposed. The worst performing cell lists for each KPI are then presented. Highlighting the worst performing cells offers the chance to improve the performance of these cells. This will improve the overall performance of GSM network in Jenien city. From the worst performing cells, we can address the main issues in Jawwal GSM network in Jenien city. Most of the KPIs indicate that there is high interference level on the BCCH carrier which is reflected from the quality in the DL.

The KPIs alone are not enough, since they give us indication about the poor performing cells. By combining the KPIs with the drive test, this will provide us with a very effective way to evaluate and enhance the performance of GSM network in Jenien city. Drive test and drive test analysis for Jawwal GSM network in Jenien city is the topic of next chapter 4.

Chapter 4

Drive Test Analysis

4.1 Introduction

As mentioned earlier, there are two approaches to evaluate the performance of alive GSM network which are, KPIs and drive tests. On the one hand, KPIs give us detailed statistics for many events in GSM cells. On the other hand, drive tests show the realistic experience of the customer. Customer's point of view is more important since it reflects the real life scenarios. The drive test system consists of the following:

1. Software for data collection installed on laptop such as TEMS[4] Investigation, Nemo[5] Outdoor etc.
2. One or more MS, depends on type of the drive test to be made. Commonly two MSs are needed one is used in connected mode (dedicated mode) to measure the QoS, handover and other serving cell parameters during the call. The other MS is used as scanner (idle mode) to scan all the available GSM900 band frequencies. The scanner MS is useful to detect the interfering cell on the serving cell. Also data cables are needed to connect these MSs to the laptop.
3. GPS receiver to place the collected samples on their corresponding coordinates on a digital map.

TEMS investigation Data Collection 8.1 is used for drive testing all over Jenien city. This drive test was performed during the interval from 01.08.2010 till 03.08.2010. TEMS investigation Route Analysis and Actix Analyzer are the post processing tools used for analyzing these collected drive test log files. It is important to note that events such as dropped calls, blocked calls, handover failure are directly related to the main KPIs that we discussed in the chapter 3. As a dropped call occurs in the drive test on a given cell, the drop call counter of that cell is incremented by one.

The advantages of the drive test are: Firstly, drive test is a powerful tool for the RF analysis and problem solving. Secondly, scanner tool used in drive test is a very good tool for detecting interfering signal. Finally, the drive test gives the exact geographical location for each sample through the connected GPS receiver. But, the drawbacks for this system are: Firstly, it is a time consuming process. Secondly, it won't include the users in buildings. Finally, the drive test gives a small sample of the users in the network located mainly on the streets [22].

There are many parameters that are gathered by the drive test. The most important parameters are: the received signal level (RXLEV) and the received signal quality (RXQUAL). These two parameters make it possible for the customer to access the GSM network and use its services.

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[4] TEMS is Ericsson professional tool used for drive test data collection. For more information visit www.ericsson.com/TEMS.

[5] Nemo is another tool from Anite used in drive test data collection. For more information visit http://www.anite.com/anite/en/solutions/nemotesting/products/nemo_outdoor

4.2 RXLEV and RXQUAL

RXLEV is the received signal power strength in units of dBm. The minimum acceptable RXLEV is commonly set to -104 dBm for the cell. While RXLEV value of -60 dBm is considered as good value. For a customer to be able to access the GSM network, it is strongly recommended that there will be a sufficient coverage with acceptable quality. The term RXLEV is defined as the signal strength at a given point and it is measured in dBm. RXQUAL is a measure of the QoS and it is given by GSM scale from 0 to 7, where 0 is the best quality and 7 is the worst. TEMS uses RXQUAL to identify the quality of a voice call or data session during the dedicated mode. RXQUAL is used to estimate the quality of GSM network service measured in terms of Bit Error Rate (BER) before channel decoding (before error correction takes place). The BER is measured and averaged every SACCH period which is 480 ms. The MS measures RXQUAL in the downlink while in the uplink the BTS handles this job [21], [23]. The following table shows how the RXQUAL is mapped from the BER percentages:

RXQUAL	BER Percentage	Assumed Value
0	< 0.2%	0.14%
1	0.2 % to 0.4%	0.28%
2	0.4% to 0.8%	0.57%
3	0.8% to 1.6%	1.13%
4	1.6% to 3.2%	2.26%
5	3.2% to 6.4%	4.53%
6	6.4% to 12.8%	9.05%
7	> 12.8%	18.1%

Table 4.1: RXQUAL with corresponding BER values.

Figure 4.1 shows how the BER is calculated in the GSM system. The BER is time averaged during the SACCH period (480 ms). Then, Table 4.1 is used to convert the BER values to RXQUAL values.

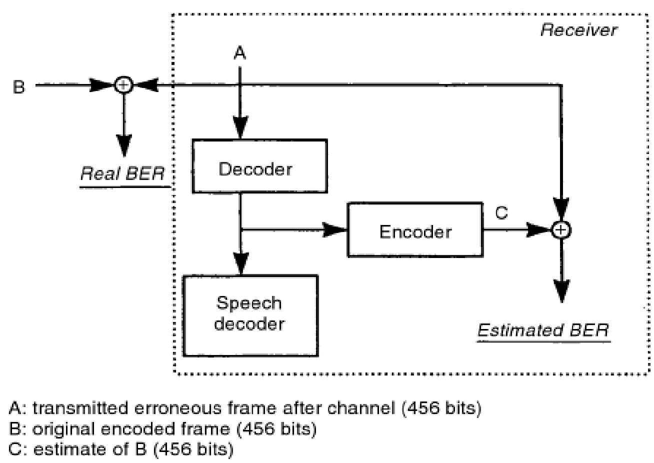

Figure 4.1: Block diagram for the estimation of the BER in GSM system. Where A is the transmitted frame after the channel, B is the original frame and C is the estimation of B.

Discontinuous transmission (DTX) is a feature used for interference reduction, which can be simply described as switching the TRUs off in order to minimize the interference within very small time interval called silent time (20ms). When this feature is used, the terms RXLEV and RXQUAL are replaced by RXLEVSUB and RXQUALSUB, respectively [25].

4.3 Drive Test Analysis

The drive test tool takes samples from the GSM network with GPS location. These collected samples include information about RXLEVSUB, RXQUALSUB, GSM events, etc. These samples can be analyzed to identify the issues in Jawwal GSM network in Jenien city. The issues can be poor RXLEVSUB, or poor RXQUALSUB which is caused by interference. Also, the combination of these two issues can exist.

Now let us start with a legend of coverage classes in terms of RXLEVSUB and RXQUALSUB. This legend will be adopted till the end of this research.

Coverage Class	Condition
Level 1	RXLEVSUB >=-70 AND RXQUALSUB<=2
Level 2	(RXLEVSUB>=-85 AND RXQUALSUB<=4) AND (RXLEVSUB< -70 OR RXQUALSUB>2)
Level 3	(RXLEVSUB>=-100 AND RXQUALSUB<=6) AND (RXLEVSUB< -85 OR RXQUALSUB>4)
Level 4	RXLEVSUB<-100 OR RXQUALSUB>6

Table 4.2: Coverage levels legend in terms of RXLEVSUB and RXQUALSUB.

Level 1 is the best level since it guarantees the best of both RXLEVSUB and RXQUALSUB. Level 2 provides the users with good RXLEVSUB and good RXQUALSUB. Level 3 provides the user with acceptable RXLEVSUB and RXQUALSUB. However, level 4 is the worst level since it combines poor RXLEVSUB with poor RXQUALSUB. Users of level 4 suffer from poor RF conditions that result in blocked calls, dropped calls, handover failures. It is obvious from the mentioned legend and from the above discussion that we need the largest samples to be in level 1, level 2 and level 3. However, low percentage in level 3 is also a good sign for a better performance and design. In the contract, level 4 must contain as low percentage as possible; in order to have a good designed GSM system.

4.3.1 Drive test analysis for Jenien city

The following table shows the current percentage of each coverage class of the collected data for overall Jenien city as function of RXLEVSUB and RXQUALSUB. The drive test is collected in August, 2010.

RXLEVSUB/ RXQUALSUB	RXQUALSUB≤ 2	2<RXQUALSUB≤ 4	4<RXQUALSUB≤ 6	RXQUALSUB> 6	Any RXQUALSUB	Coverage Class	%
RXLEVSUB≥-70	65.46	6.97	7.56	4.99	84.98	Level 1	65.5
-70 ≥ RXLEVSUB ≥ -85	6.54	2.16	2.71	2.28	13.69	Level 2	15.7
-85≥ RXLEVSUB ≥-100	0.28	0.25	0.3	0.45	1.28	Level 3	11.1
RXLEVSUB ≤ -100	0.02	0	0	0.02	0.04	Level 4	7.76
Any RXLEVSUB	72.3	9.38	10.75	7.74	100	Total	100

Table 4.3: Percentage distribution of coverage classes of Jawwal GSM network in Jenien city in August, 2010.

Table 4.3 shows the percentage distribution of coverage classes as obtained from the data collected during the drive test. According to Table 4.3, about 7.76% of the samples lie in level 4. Users in this level experience serious issues in QoS when they are connected to the network and mostly they are not allowed to be connected at all due to high interference. The ultimate goal of this research is to lower the 7.76% in level 4 and to increase the percentage of level 1 or level 2.

As discussed earlier the RXLEVSUB and RXQUALSUB are important terms in GSM. Thus, in the following, the distributions of the RXLEVSUB and RXQUALSUB for the drive test of overall Jenien city are listed.

Figure 4.2 shows a distribution of RXLEVSUB versus the number of samples for the overall drive test of Jenien city.

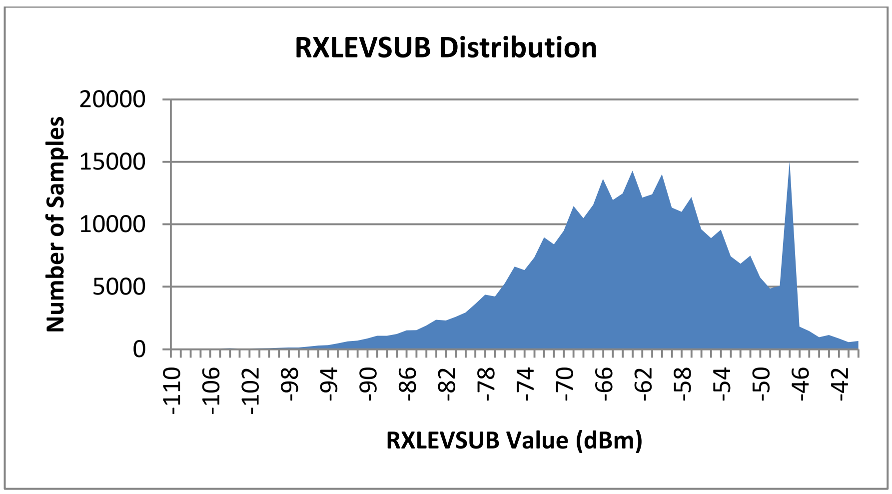

Figure 4.2: RXLEVSUB distribution in the Jenien city drive test in August, 2010.

From Figure 4.2, it is noted that most of the samples are within the interval from -42 to -85 dBm with average of -63.39 dBm and with standard deviation of 10.43. Although there is a small number of samples with RXLEVSUB less than -85 dBm, but they only represent small portion of the overall samples. The planned sites in Jenien city discussed in chapter 2 were placed to solve these issue. Figure 4.2 also shows that there is a sharp spike near the value -46 dBm, this is because of the fact that Jenien city is in general a good covered area so there is large number of samples with very good RXLEVSUB values specially near the sites. Also this spike comes from the fact that the drive test car sometimes stuck in a traffic jam near RF site, so many samples are taken with very good RXLEVSUB.

Now let us move in our discussion to the RXQUALSUB distribution for Jenien city, which is shown in the Figure 4.3.

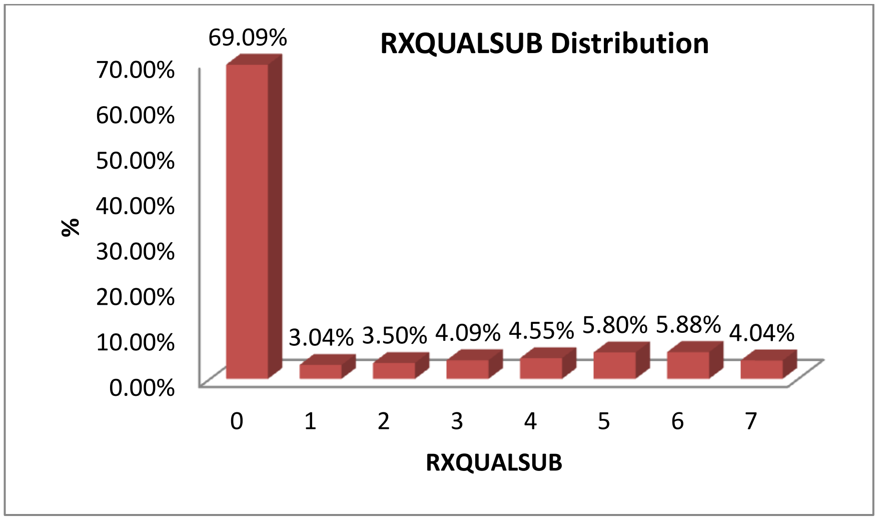

Figure 4.3: RXQUALSUB distribution of Jenien city drive test in August, 2010.

According to Figure 4.3 about 69% of the samples have 0 RXQUALSUB which is the best RXQUALSUB. However, samples with RXQUALSUB of 6 it is about 6%, and with RXQUAL of 7 about 4%. It is common to denote the RXQUALSUB of 6 and 7 as poor RXQUALSUB. So, in this drive test of Jenien city about 10% of the samples are with poor RXQUALSUB.

Now, a methodology for design validation is adopted. In that methodology, the reasons that lead to the poor design are investigated. Intensive work on those reasons will then take place. That will result in better network performance. Firstly, let us adopt and define the possible reasons that may affect the design of GSM network (see Table 4.4). Secondly, after investigating the drive test of Jenien city we can assign to each reason its percentage. In other words, how much that specific reason is affecting the performance of GSM network in Jenien city (see Table 4.5).

Cause	**Definition**		
Interference	Quality > 3	Level >= -85 dBm	server is dominant
Poor Level	Quality ≤ 3	Level < -85 dBm	Server is dominant
Poor Quality and Poor Level	Quality > 3	Level < -85 dBm	Server is dominant
No Dominance	Quality ≤ 3	Level >= -85 dBm	Server is not dominant
Interference and No Dominance	Quality > 3	Level >= -85 dBm	Server is not dominant
Poor Level and No Dominance	Quality ≤ 3	Level < -85 dBm	Server is not dominant
Poor Quality, Poor Level and No Dominance	Quality > 3	Level < -85 dBm	Server is not dominant

Table 4.4: Possible reasons of poor design in GSM network with definitions.

Cause	Percent
Interference	44.97%
Poor Level	3.78%
Poor Quality and Poor Level	2.90%
No Dominance	31.87%
Interference and No Dominance	14.48%
Poor Level and No Dominance	1.03%
Poor Quality, Poor Level and No Dominance	0.96%

Table 4.5: Poor design reasons with their percentage for Jenien city in August, 2010.

According to Table 4.5, interference plays a major role in affecting the performance of the GSM network in Jenien city with a percentage of about 44.97%. As said earlier, interference is translated as poor RXQUALSUB or simply poor QoS on the GSM network in Jenien city. No dominance is in the second place. The no dominance is the case in which the serving cell and its neighbors are within only 5 dB separation. That will make no dominant cell in a given area which leads in repeated handover that results in poor RXQUALSUB. The poor level is another reason with small percentage of about 4% which will be solved after activating the planned sites in Jenien city.

"Divide and Conquer" is an old saying and this research is not an exception. So, we will partition Jenien city to neighborhoods. This will be followed with detailed discussion for each area.

In the analysis, Actix software[6] is used to analyze the drive test data. we start by all the areas of Jenien city with their names and the details of each area are then given

4.3.2 Mrah area

This is the first part of Jenien city, it is urban area with mostly residential users. The serving sites in this area are JENI02, JENI15, JENI04, JENI12. There are also planned sites in this area which are JENI20, JENI23 and JENI24.

For this area only a number of figures will be presented. These figures include:

1. RXLEVSUB for Mrah area: Figure 4.4 shows the real drive test map with the samples that represents the coverage (RXLEVSUB) placed on it. This is very important since it shows the geographical location for each sample. Note that the exact number of samples for each level is shown between parenthesis in the top right angle.
2. RXQUALSUB for Mrah area: Figure 4.5 shows a drive test map with samples of RXQUALSUB.
3. Serving BCCH for Mrah area: Figure 4.6 shows the BCCH carrier mapped into the geographical location of that area. The serving BCCH map is used with the scanning data to find the interfering BCCH on the serving BCCH. In the case of no interference

[6] Actix software is professional software used as post processing tool for TEMS drive test log files. For more information, the reader can visit the link www.actix.com.

(good RXQUALSUB), the connected mode MS and the scanning MS during the drive test will give the same reading for one BCCH/BSIC. In the case of interference (poor RXQUALSUB) the connected mode MS will give one BCCH/BSIC and the scanning mode MS will give the same BCCH with different BSIC. This means that there is one BCCH used in two cells that are close to each other. That results in co-channel interference. The BCCH/BSIC combination is used to identify the interfering cell.

4. RXQUALSUB with dropped calls for Mrah area: Figure 4.6 shows the RXQUALSUB with TCH dropped calls. Also it shows the poor RXQUALSUB samples of the collected drive test that leads to 4 dropped calls. This is very important since it locates the dropped calls on the map.
5. Serving Cell Identity (CI): Figure 4.8 shows the serving cell at each sample. This is very important to identify the service area for each cell. This CI is a unique code for each cell. The CI is a 5 digits number, the first two digits are 55 meaning that the site is located in Jenien city. The next two digits are the site number which are the number taken from the site I.D part. The last digit is the cell I.D which is 1 for cell A, 2 for cell B and 3 for cell C. Take an example for JENI02C, the CI is 55023. 55 is for Jenien city, 02 is the number of the site and 3 is for cell C.
6. Serving BSIC: Figure 4.9 shows the serving BSIC which is used to differentiate between the co-BCCH cells. This is a very helpful tool for identifying the interfering cells.

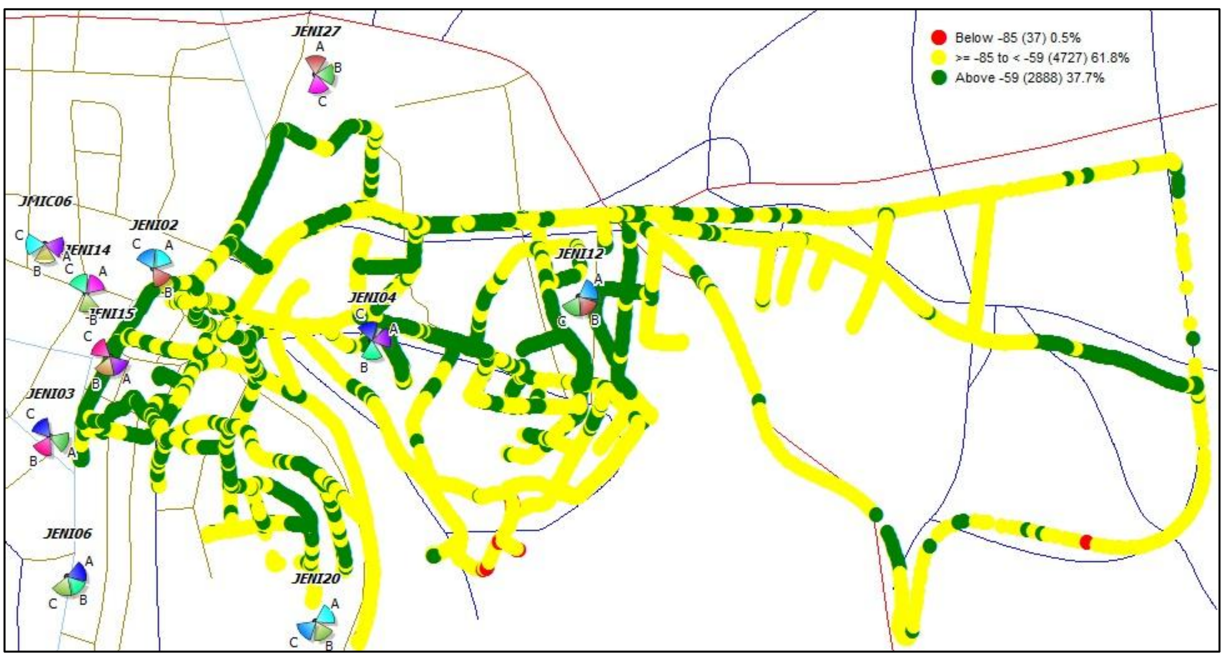

Figure 4.4: RXLEVSUB for Mrah area in August, 2010.

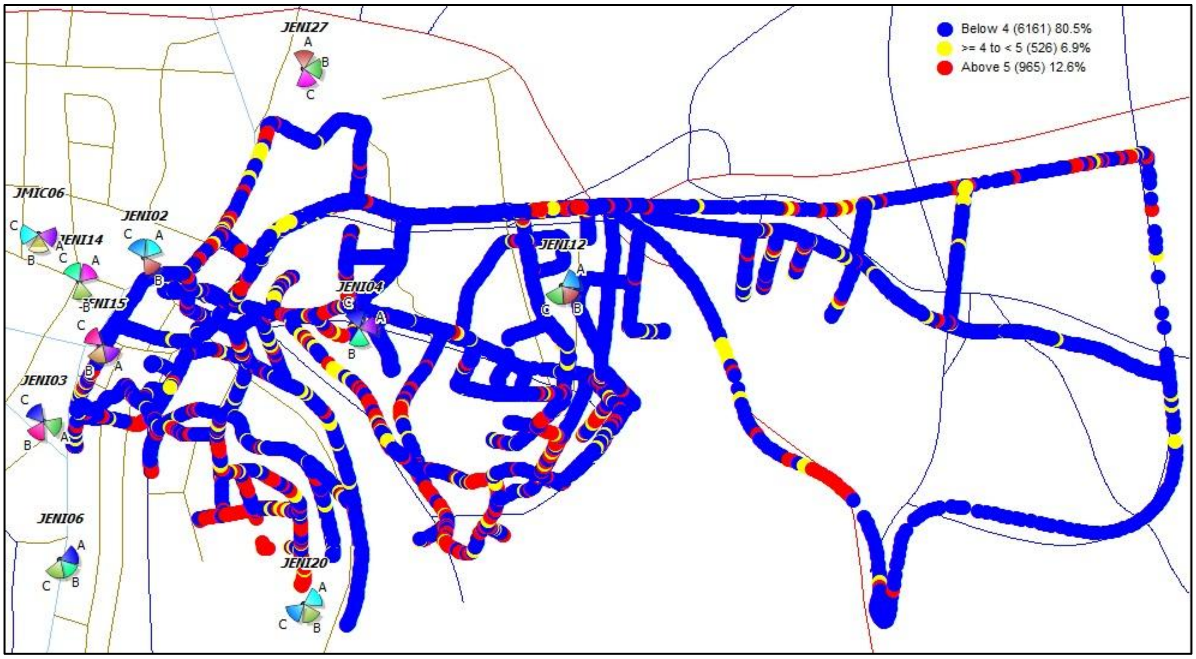

Figure 4.5: RXQUALSUB for Mrah area in August, 2010.

Figure 4.6: Serving BCCH for Mrah area in August, 2010.

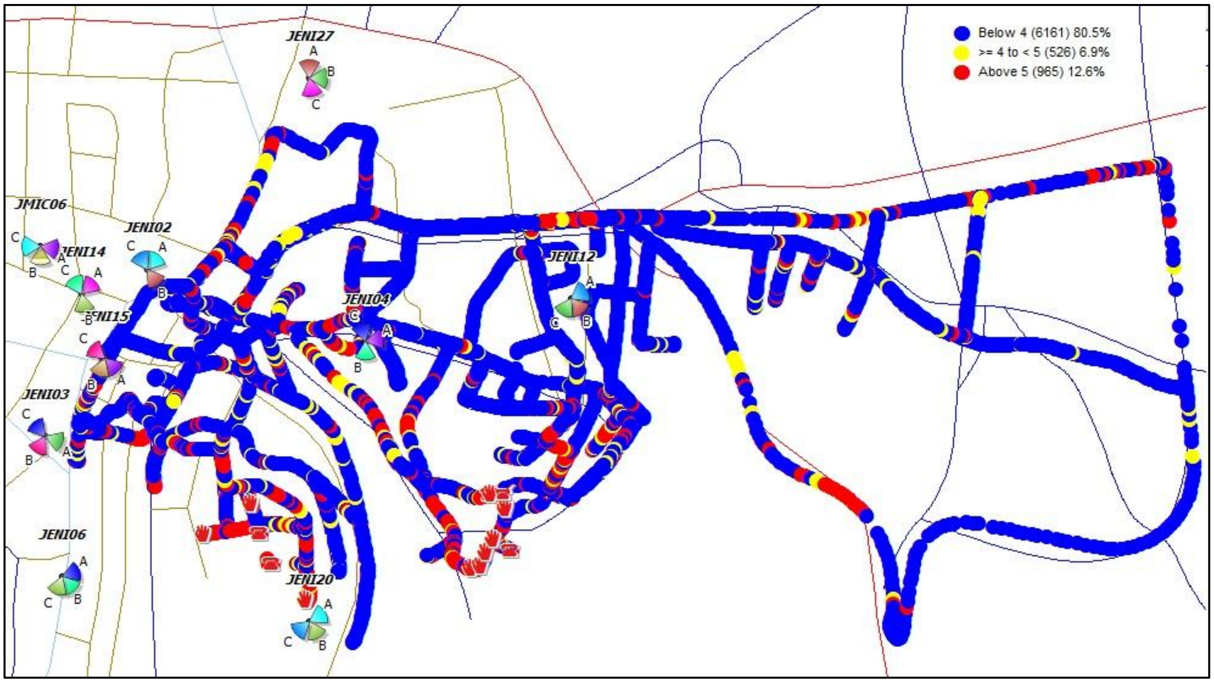

Figure 4.7: RXQUAL with dropped calls for Mrah area in August, 2010.

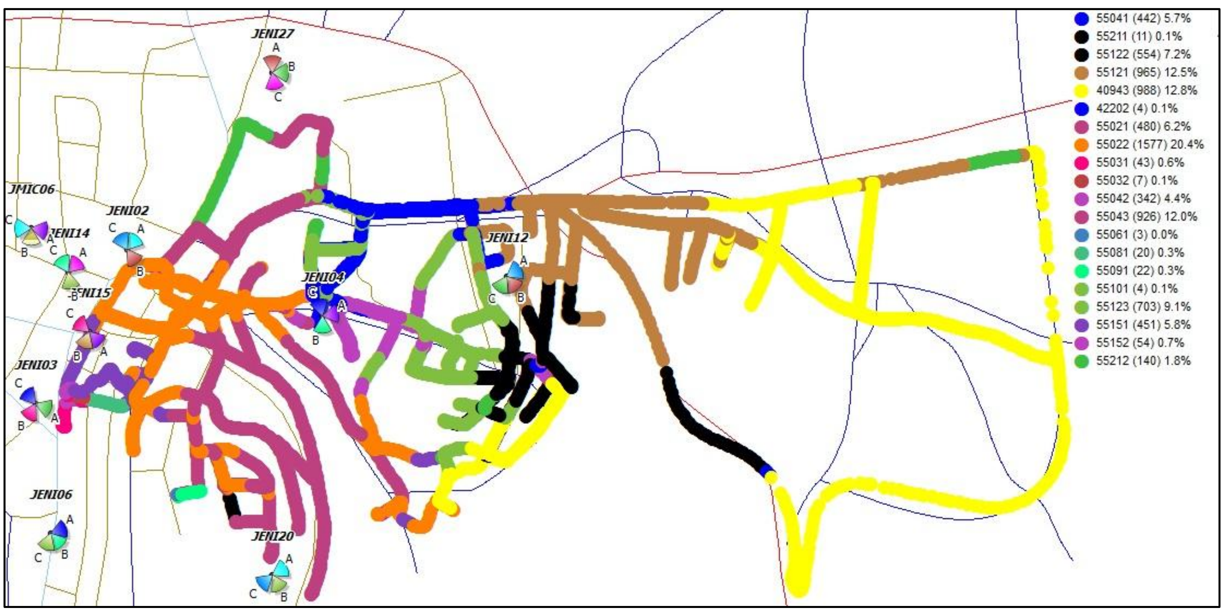

Figure 4.8: Serving Cell Identity (CI) for Mrah area in August, 2010.

Figure 4.9: Serving BSIC for Mrah area in August, 2010.

Table 4.6 shows the distribution of the different coverage classes in terms of RXLEVSUB and RXQUALSUB for Mrah area in August, 2010.

RXLEVSUB/ RXQUALSUB	RXQUALSUB≤ 2	2<RXQUALSUB≤ 4	4<RXQUALSUB≤ 6	RXQUALSUB> 6	Any RXQUALSUB	Coverage Class	%
RXLEVSUB≥-70	71.43	3.29	4.79	3.48	82.99	Level 1	71.43
-70 ≥ RXLEVSUB ≥ -85	11.47	2.16	1.88	1.32	16.83	Level 2	16.92
-85≥ RXLEVSUB ≥-100	0.09	0.09	0	0	0.18	Level 3	6.85
RXLEVSUB ≤ -100	0	0	0	0	0	Level 4	4.8
Any RXLEVSUB	82.99	5.54	6.67	4.8	100	Total	100

Table 4.6: Percentage distribution of coverage classes of Jawwal GSM network for Mrah area in August, 2010.

According to Table 4.6, the following points are noticed:

1. More than 71% of the samples are considered in level 1 which is a level of excellent coverage and best quality. It is a good indication that 71% of the samples are within this level. So, this part of Jenien city is a well designed part, but additional improvements could be made to boost the RXQUALSUB further more.
2. About 5% in level 4 which should be reduced.
3. About 17% in level 2. It is a good percentage for this level. Nevertheless, any increase of this level will be good.
4. About 7% in level 3 which is a low percentage.

The distribution of RXLEVSUB and RXQUALSUB for the collected data from the drive test of Mrah area are presented in Figure 4.10 and Figure 4.11, respectively.

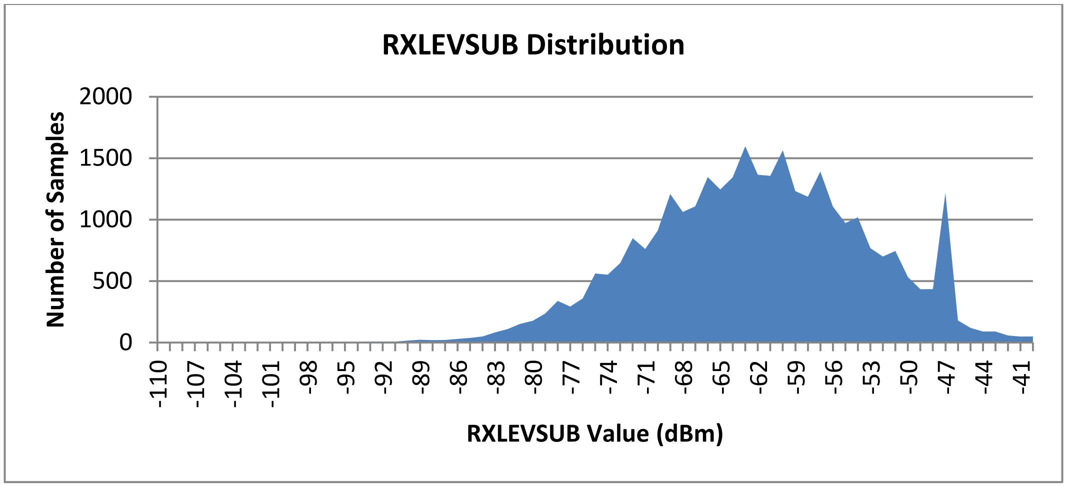

Figure 4.10: RXLEVSUB distribution for Mrah area in August, 2010.

According to Figure 4.10, the collected samples are within the interval from -42 to -85 dBm with average of 62.02 dBm and standard deviation of 8.73. This is a good RXLEVSUB distribution since a large amount of the bins have excellent RXLEVSUB. However, there is small number of samples with RXLEVSUB less than -85 dBm.

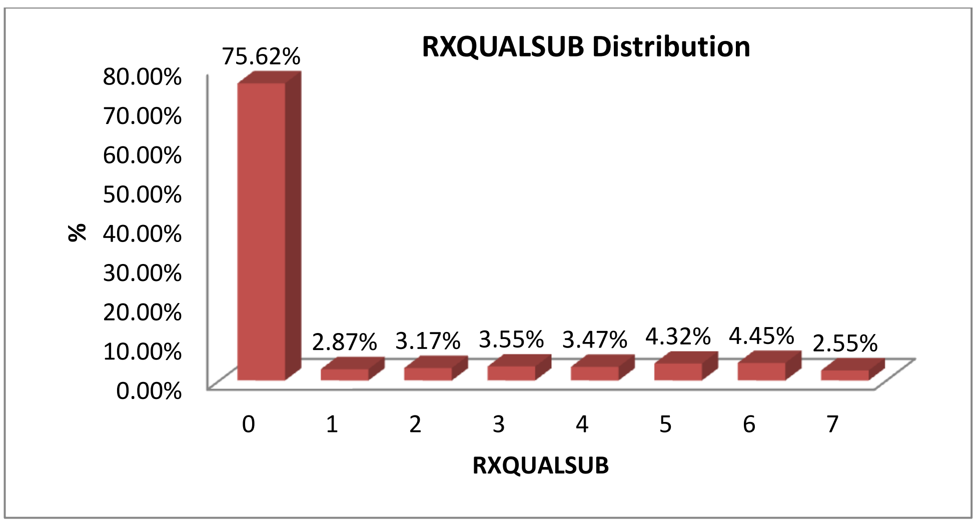

Figure 4.11: RXQUALSUB distribution for Mrah area in August, 2010.

According to Figure 4.11, more than 75% percent of the samples have 0 RXQUALSUB which is the best RXQUALSUB. However, there are 4.5% of samples with RXQUALSUB of 6 and about 2% of the samples with RXQUAL of 7. This makes about 7% of the samples having poor quality.

Table 4.7 shows the reasons that make the poor performance in Mrah area from the drive test collected in August, 2010.

Cause	Percent
Interference	64.5%
Poor level	0.3%
Poor quality and poor level	1.8%
No dominance	22.1%
Interference and no dominance	10.9%
Poor level and no dominance	0.0%
Poor quality, poor level and no dominance	0.3%

Table 4.7: Poor design reasons with their percentages for Mrah area in August, 2010.

From table 4.7, it is easy to notice that the interference is the major issue in Mrah area where 64.5% of poor design is due to interference. Another serious issue is “No dominance” which is the case of having more than two neighbors within 5 dBm deviation from the server. This is caused mainly from cells overlapping that will make common coverage areas between the cells.

4.3.3 Ballad area

Now let us move the discussion to another area which is the commercial part of Jenien city. It is the commercial center in the middle of Jenien city and considered as dense urban area. The serving sites in this area are JENI01, JENI02, JENI03, JENI11, JENI14, JENI15 and JENI21. There are no planned sites in this area till date when the research was elaborated.
Table 4.8 shows the percentage of each coverage level as a function of RXLEVSUB and RXQUALSUB.

RXLEVSUB/ RXQUALSUB	RXQUALSUB≤ 2	2<RXQUALSUB≤ 4	4<RXQUALSUB≤ 6	RXQUALSUB> 6	Any RXQUALSUB	Coverage Class	%
RXLEVSUB≥-70	74.2	7.2	4.8	95.2	95.2	Level 1	74.2
-70 ≥ RXLEVSUB ≥ -85	2.6	1	0.7	4.8	4.8	Level 2	10.8
-85≥ RXLEVSUB ≥-100	0	0	0	0	0	Level 3	9.5
RXLEVSUB ≤ -100	0	0	0	0	0	Level 4	5.5
Any RXLEVSUB	76.8	8.2	5.5	100	100	Total	100

Table 4.8: Percentage distribution of coverage classes of Jawwal GSM network for Ballad area in August, 2010.

From Table 4.8, the following points are noticed:

1. More than 74% of the collected samples for Ballad area are in level 1 which is an excellent percentage especially because this area is the city center.
2. About 5.5% in level 4. This percentage should be as low as possible.
3. About 11% in level 2.
4. About 9.5% in level 3.

Figure 4.12 and Figure 4.13 show the RXLEVSUB and RXQUALSUB distribution plots for this area, respectively.

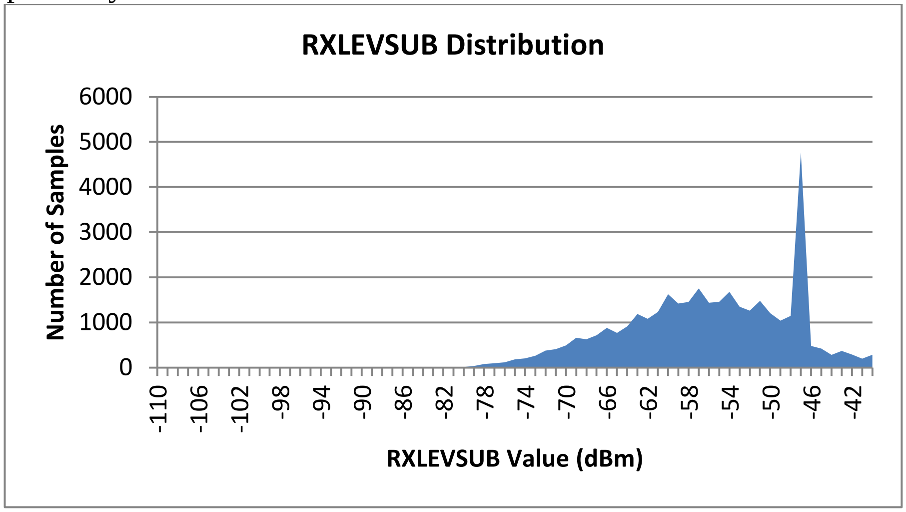

Figure 4.12: RXLEVSUB distribution for Ballad area in August, 2010.

From Figure 4.12, it is noted that Ballad area is a well covered area since all the coverage samples are within -42 and -80 dBm with average of -56.12 dBm and standard deviation of 8.06. This distribution for RXLEVSUB shows a good behavior since all samples are within a good range.

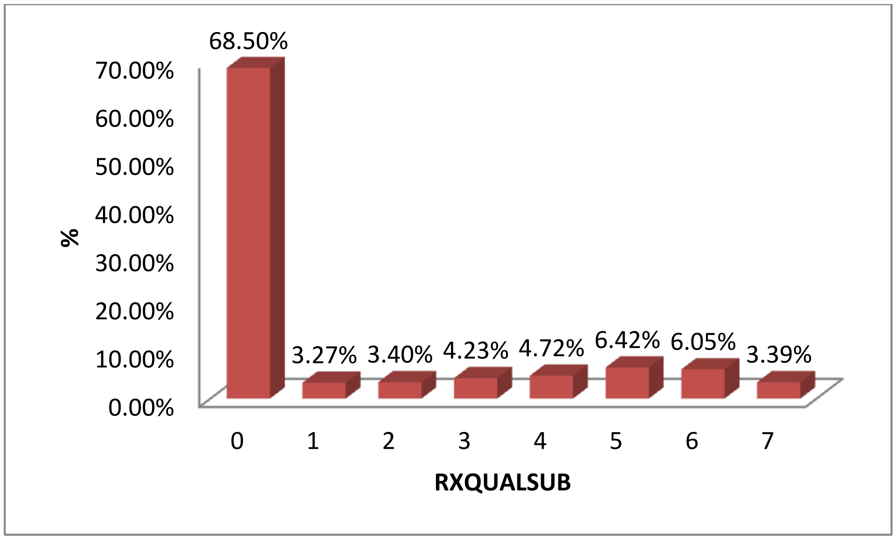

Figure 4.13: RXQUALSUB distribution for Ballad area in August, 2010.

From figure 4.13, it is noted that 68.5% of the collected samples in Ballad area drive have the best RXQUALSUB which is 0. However, the main problems are with the RAQUALSUB of 6 and 7 which is about 9.44%.

Now, the poor design classification will be introduced so as we can identify the main reasons behind the poor design. This will enable us to enhance the network performance in this area.

Cause	Percent
Interference	71.8%
Poor level	0.0%
Poor quality and poor level	0.0%
No dominance	14.4%
Interference and no dominance	13.8%
Poor level and no dominance	0.0%
Poor quality, poor level and no dominance	0.0%

Table 4.9: Poor design reasons with their percentage for Ballad area in August, 2010.

From table 4.9, interference plays a major role in affecting the network performance with a percentage of 71.8%. No dominance is in the second place. In addition, one can notice that the poor level has a percentage of 0%. This is obvious from the RXLEVSUB distribution shown in Figure 4.12.

4.3.4 Hadaf area

This area is a residential area with the sites JENI05, JENI16 and JENI18 as serving sites. The only planned site in this area is JENI26.

RXLEVSUB/ RXQUALSUB	RXQUALSUB≤ 2	2<RXQUALSUB≤ 4	4<RXQUALSUB≤ 6	RXQUALSUB> 6	Any RXQUALSUB	Coverage Class	%
RXLEVSUB≥-70	57.71	8.09	8.4	6.26	80.46	Level 1	57.71
-70 ≥ RXLEVSUB ≥ -85	3.66	2.9	3.66	2.14	12.36	Level 2	14.65
-85≥ RXLEVSUB ≥-100	1.83	1.07	0.92	3.05	6.87	Level 3	15.88
RXLEVSUB ≤ -100	0	0	0	0.31	0.31	Level 4	11.76
Any RXLEVSUB	63.2	12.06	12.98	11.76	100	Total	100

Table 4.10: Percentage of coverage classes of Jawwal GSM network for Hadaf area in August, 2010.

From Table 4.10, one can notice that:

1. Level 1 is with only about 58%. This is a low percentage for the best level. Here extensive work must be made in order to increase the percentage of that level.
2. Level 4 is 12%. This is a very high percentage for this bad level. Extensive work will be done here to lower this percentage.
3. Level 2 is 15%.
4. Level 3 has a value of 12%.

Figure 4.14 and Figure 4.15 show the RXLEVSUB and RXQAULSUB distributions, respectively.

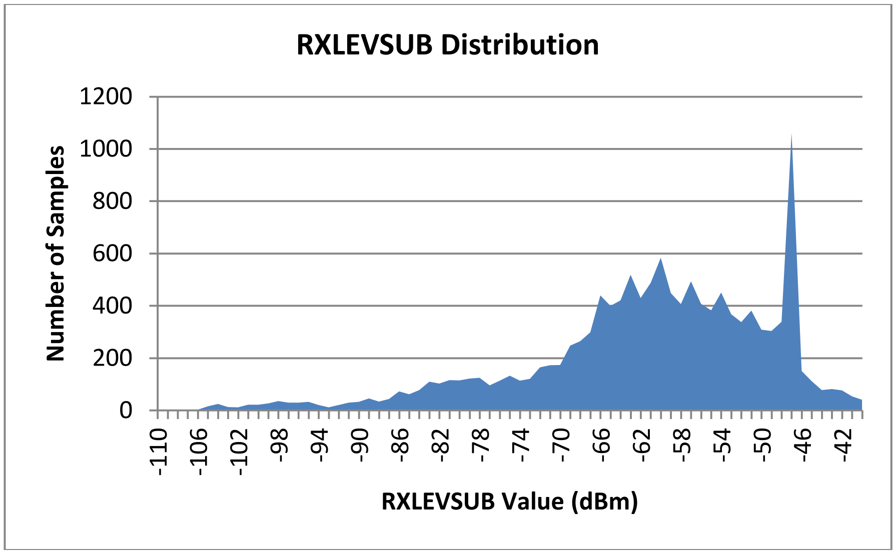

Figure 4.14: RXLEVSUB distribution for Hadaf area in August, 2010.

From Figure 4.14, it is shown that there is a number of samples with coverage of less than -85 dBm. The average of these samples equals -61.19 dBm and the standard deviation is 12.09. This leads us to the planned site in this area which is JENI26.

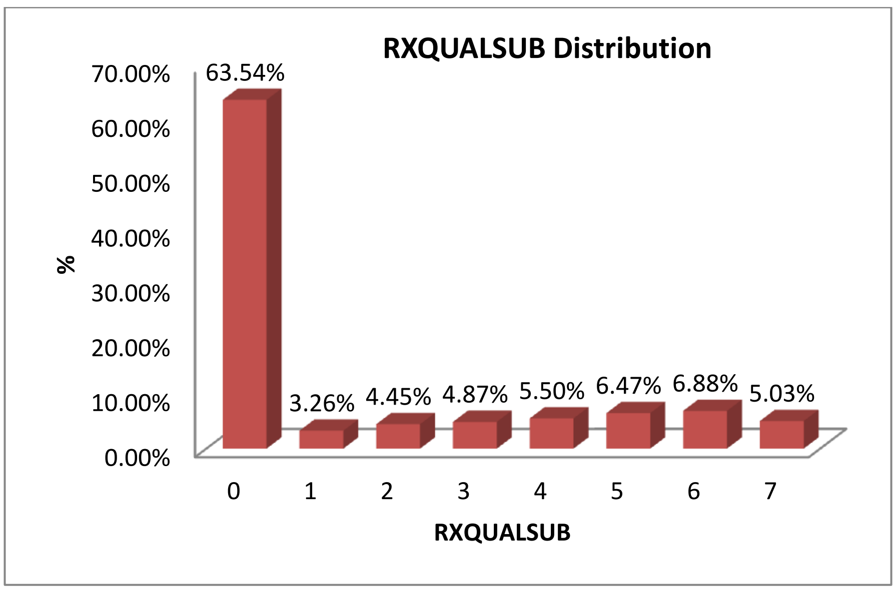

Figure 4.15: RXQUALSUB distribution for Hadaf area in August, 2010.

According to Figure 4.15, about 63.5% of samples lies in the best RXQUALSUB value of 0. However, about 7% of the samples have RXQUALSUB of 6 and about 5% have a value of 7. This results in a high percentage of about 12% of poor quality samples.

Now let’s check the poor design criteria for Hadaf area drive test data (see Table 4.11). This will help in determining the reasons for poor design.

Cause	Percent
Interference	60.8%
Poor level	3.9%
Poor quality and poor level	9.8%
No dominance	10.9%
Interference and no dominance	12.4%
Poor level and no dominance	0.6%
Poor quality, poor level and no dominance	1.6%

Table 4.11: Poor design reasons with their percentages for Hadaf area in August, 2010.

According to Table 4.11, the interference is the main cause of the poor design in this area with 60.8%. The no dominance is in the second place followed by poor coverage. To avoid the problem of poor coverage, a new site is planned in this area which is site JENI26.

4.3.5 Industrial area

This is an industrial area and it is considered as dense urban area. JENI12, JENI13 and JENI21 are the serving sites and JENI27 is a planned site in this area. The percent of the RXLEVSUB and RXQUALSUB distributions are tabulated in Table 4.12.

RXLEVSUB/ RXQUALSUB	RXQUALSUB≤ 2	2<RXQUALSUB≤ 4	4<RXQUALSUB≤ 6	RXQUALSUB> 6	Any RXQUALSUB	Coverage Class	%
RXLEVSUB≥-70	70.31	10.56	10.2	6.38	97.45	Level 1	70.31
-70 ≥ RXLEVSUB ≥ -85	0.91	0.18	0.55	0.91	2.55	Level 2	11.65
-85≥ RXLEVSUB ≥-100	0	0	0	0	0	Level 3	10.75
RXLEVSUB ≤ -100	0	0	0	0	0	Level 4	7.29
Any RXLEVSUB	71.22	10.74	10.75	7.29	100	Total	100

Table 4.12: Percentage of coverage classes of Jawwal GSM network for Industrial area in August, 2010.

From Table 4.12, the following comments can be drawn:

1. About 70% of the collected samples in the Industrial area drive test lie in level 1. This is a good percentage and can be increased.
2. About 8% of the samples are in the level 4. The percentage of this level must be lowered and that will happen when we pull the other levels up.
3. About 12% of the samples are in level 2.
4. About 11% of the samples are in level 3.

Figure 4.16 and Figure 4.17 show the RXLEVSUB and RXQUALSUB distributions, respectively.

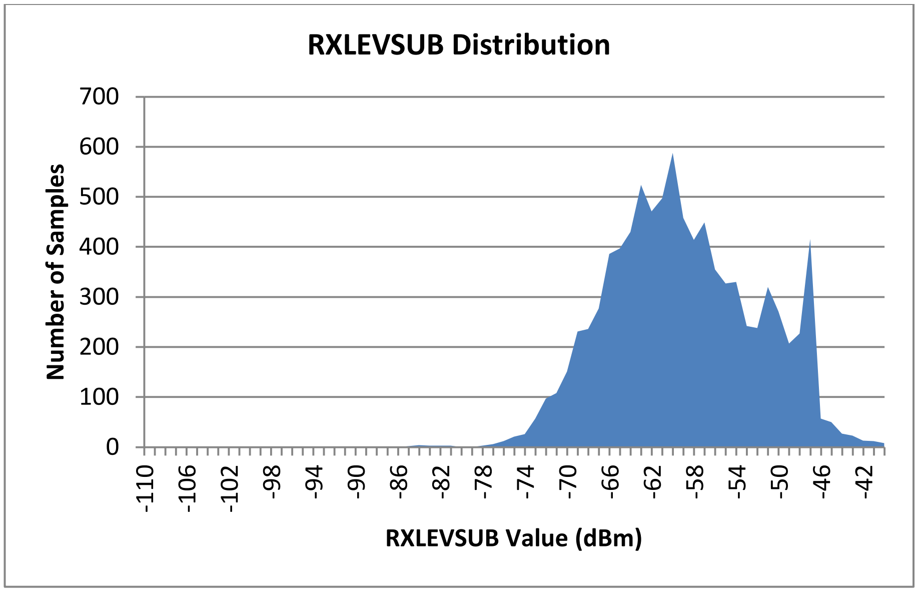

Figure 4.16: RXLEVSUB distribution for Industrial area in August, 2010.

According to Figure 4.16, there is a good coverage in this area as all samples are on the good range for RXLEVSUB. The samples of RXLEVSUB are within the interval from -42 to -85 dBm. The average RXLEVSUB of the above collected samples is -58.96 dBm and the standard deviation is 6.98.

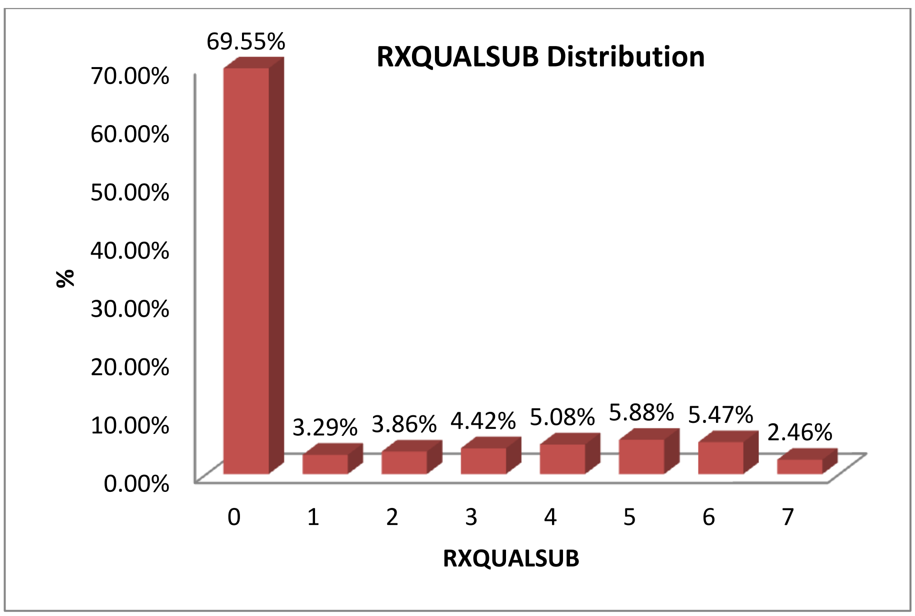

Figure 4.17: RXQUALSUB distribution for the Industrial area in August, 2010.

From Figure 4.17, it is noted that about 70% of the samples in the drive test of Industrial area are with the best RXQUALSUB of 0. Nevertheless, about 5.4% corresponds to RXQUALSUB of 6 and about 2.5% corresponds to RXQUALSUB of 7. This makes a total of 8% of poor quality.

Table 4.13 shows the poor design validation approach which gives the reasons for the main issues in Industrial area.

Cause	Percent
Interference	59.2%
Poor level	0.0%
Poor quality and poor level	0.0%
No dominance	26.3%
Interference and no dominance	14.5%
Poor level and no dominance	0.0%
Poor quality, poor level and no dominance	0.0%

Table 4.13: Poor design reasons with their percentage for Industrial area in August, 2010.

From table 4.13, it is obvious that the interference is the major issue with a percentage of 59.2%. The no dominance reason is in the second place. This will be cured when JENI27 is activated which is dedicated to cover that area.

4.3.6 Swettat area

This is another residential area with JENI03, JENI06, JENI10 and JENI17 as the serving sites. Planned sites in this area are JENI20 and JENI25.
Table 4.14 shows the distributions of all different levels of coverage in terms of RXLEVSUB and RXQUALSUB.

RXLEVSUB/ RXQUALSUB	RXQUALSUB≤ 2	2<RXQUALSUB≤ 4	4<RXQUALSUB≤ 6	RXQUALSUB> 6	Any RXQUALSUB	Coverage Class	%
RXLEVSUB≥-70	55.22	4.39	5.05	3.15	67.81	Level 1	55.22
-70 ≥ RXLEVSUB ≥ -85	14.90	3.39	5.88	5.30	29.47	Level 2	22.68
-85≥ RXLEVSUB ≥-100	0.58	0.58	0.75	0.83	2.74	Level 3	12.84
RXLEVSUB ≤ -100	0.00	0.00	0.00	0.00	0.00	Level 4	9.28
Any RXLEVSUB	70.70	8.36	11.68	9.28	100	Total	100

Table 4.14: Percentage of coverage classes of Jawwal GSM network for Swettat area in August, 2010.

According to Table 4.14, the following comments can be pointed out:

1. About 55% of the samples are in Level 1. This percentage is considered very low and should be increased.
2. About 9% of the samples are in level 4. This percentage should be reduced.
3. About 23% of the samples are in level 2 which is good.
4. About 13% of the samples are in level 3 which is good.

Figure 4.18 and Figure 4.19 show the RXLEVSUB and RXQUALSUB distributions for Swettat area, respectively.

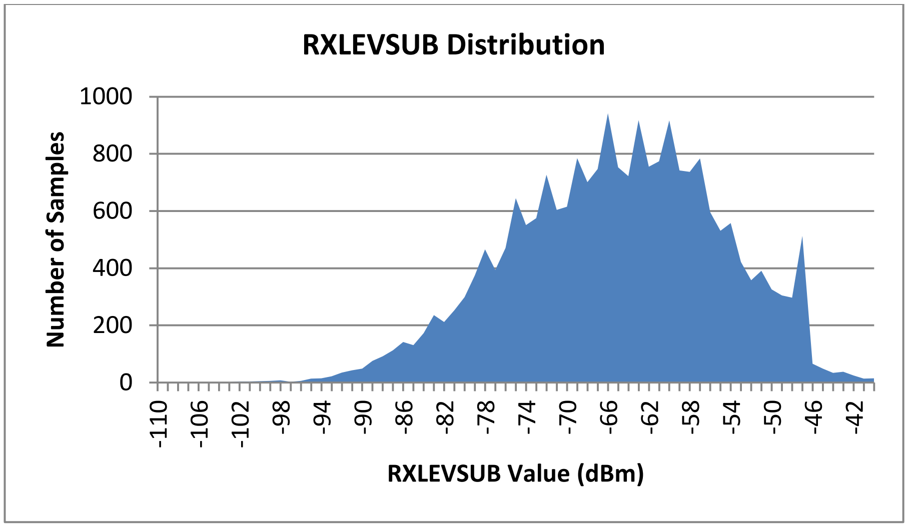

Figure 4.18: RXLEVSUB distribution for Swettat area in August, 2010.

From figure 4.18, it is noted that this area has good coverage but there are some bad covered spots with RXLEVSUB less than -85 dBm. This can be cured by the two new planned sites JENI20 and JENI25. The average of RXLEVSUB in this area is -65.23 dBm and with standard deviation of 10.21.

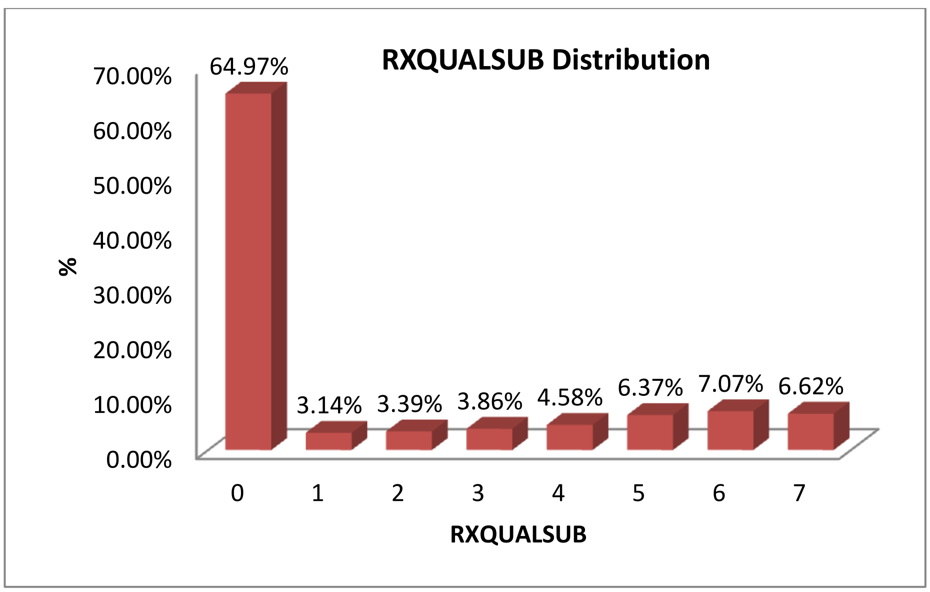

Figure 4.19: RXQUALSUB distribution for Swettat area in August, 2010.

According to Figure 4.19, the best RXQUALSUB value of 0 has about 64% of the samples in the drive test of Swettat area collected in August, 2010. But, around 13% of the samples correspond to poor RXQUALSUB values of 6 and 7. This high percentage of poor RXQUALSUB should be reduced.

The poor design validation is shown in Table 4.15.

Cause	Percent
Interference	62.1%
Poor level	2.4%
Poor quality and poor level	5.2%
No dominance	15.9%
Interference and no dominance	12.5%
Poor level and no dominance	0.4%
Poor quality, poor level and no dominance	1.4%

Table 4.15: Poor design reasons with their percentage for Swettat area in August, 2010.

It is noted from Table 4.15 that 62.1% is caused by the interference. The poor coverage will be cured by the new planned sites JENI20 and JENI25.

4.3.7 Kharoubeh area

This is also a residential area in Jenien city with serving sites JENI07, JENI13 and JENI21. JENI29 is a planned site in this area.
Table 4.16 shows the coverage classes in Kharoubeh area as a function of measured RXLEVSUB and RXQUALSUB.

RXLEVSUB/ RXQUALSUB	RXQUALSUB≤ 2	2<RXQUALSUB≤ 4	4<RXQUALSUB≤ 6	RXQUALSUB> 6	Any RXQUALSUB	Coverage Class	%
RXLEVSUB≥-70	57.04	11.30	12.83	11.85	93.02	Level 1	57.04
-70 ≥ RXLEVSUB ≥ -85	0.98	0.56	2.09	3.35	6.98	Level 2	12.84
-85≥ RXLEVSUB ≥-100	0	0	0	0	0	Level 3	14.92
RXLEVSUB ≤ -100	0	0	0	0	0	Level 4	15.20
Any RXLEVSUB	58.02	11.86	14.92	15.2	100	Total	100

Table 4.16: Percentage of coverage classes of Jawwal GSM network for Kharoubeh area in August, 2010.

From the above table, we can note the following:

1. 57% of the collected drive test in August, 2010 for Kharoubeh area lie in level 1. This is a low percentage and it must be increased.
2. 15% of the samples in level 4. This area is very bad because of the high percentage in level 4.
3. 13% for level 2 is good.
4. 15% for level 3 is good.

Now it is the time to demonstrate the RXLEVSUB and RXQUALSUB for Kharoubeh area, starting with RXLEVSUB distribution figure shown in Figure 4.20.

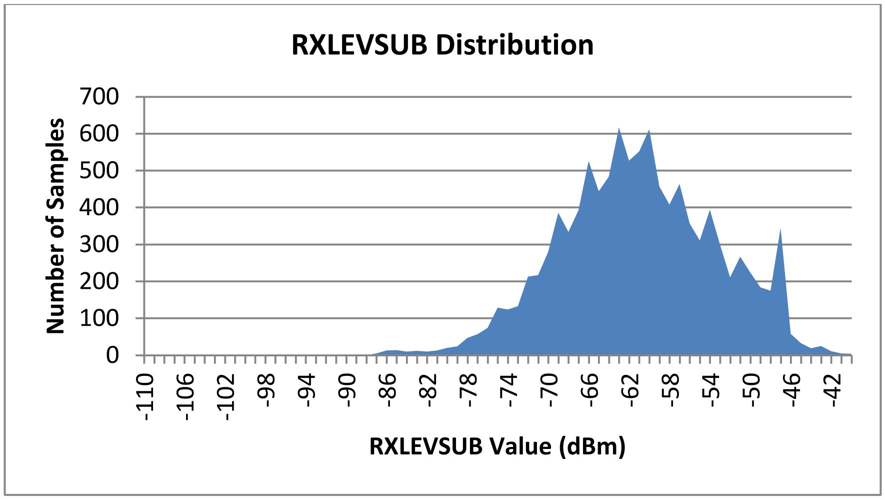

Figure 4.20: RXLEVSUB distribution for Kharoubeh area in August, 2010.

As shown in Figure 4.20, it is obvious that this area has a good coverage. But there is also a planned site to boost the coverage which is JENI29. The average RXLEVSUB is -61.05 dBm and the standard deviation is 7.72.
RXQUALSUB distribution is shown in Figure 4.21.

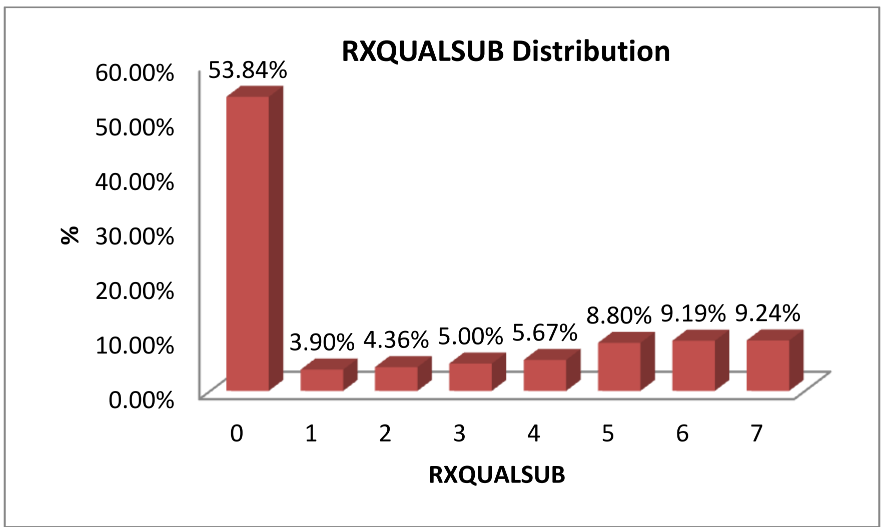

Figure 4.21: RXQUALSUB distribution for Kharoubeh area in August, 2010.

This area has about 53% of the samples with best RXQUALSUB value of 0. But it suffers from large percents with RXQUALSUB of 6 and 7 namely about 9% each. This is a very bad quality with high percentage of 18% for both the RXQUALSUB of 6 and 7 together. This area has the most poor RXQUALSUB in Jenien city.
Now let’s move to the poor coverage tables to identify the main reasons for the poor design which will be as expected from the interference mainly.

Cause	Percent
Interference	65.0%
Poor level	0.0%
Poor quality and poor level	0.4%
No dominance	14.3%
Interference and no dominance	20.3%
Poor level and no dominance	0.0%
Poor quality, poor level and no dominance	0.0%

Table 4.17: Poor design reasons with their percentage for Kharoubeh area in August, 2010.

As expected, the main cause of the poor design is the interference with a percent of 65%. The second reason is the no dominance. The cause of these problems is that this area has many cells shooting from far distance and that makes interference and no dominance very sever.

4.3.8 Jabryat area

This area is a high mountain residential area. The serving sites in this area are JENI01, JENI05, JENI08, JENI09, JENI16 and JENI18. The only planned site is the JENI19.
The following table is the table of coverage classes distribution by considering the RXLEVSUB and RXQUALSUB for that area under test.

RXLEVSUB/ RXQUALSUB	RXQUALSUB≤ 2	2<RXQUALSUB≤ 4	4<RXQUALSUB≤ 6	RXQUALSUB> 6	Any RXQUALSUB	Coverage Class	%
RXLEVSUB≥-70	75.17	7.88	6.09	3.05	92.19	Level 1	75.17
-70 ≥ RXLEVSUB ≥ -85	3.31	0.93	2.25	1.32	7.81	Level 2	12.12
-85≥ RXLEVSUB ≥-100	0	0	0	0	0	Level 3	8.34
RXLEVSUB ≤ -100	0	0	0	0	0	Level 4	4.37
Any RXLEVSUB	78.48	8.81	8.34	4.37	100	Total	100

Table 4.18: Percentage of coverage classes of Jawwal GSM network for Jabryat area in August, 2010.

From table 4.18, it is noted that:

1. Level 1 is 75% which is considered as excellent percentage and this number should be maintained or even increased.
2. 4% for level 4, this level must be lowered.
3. 12% for level 2.
4. 8% for level 3.

The RXLEVSUB distribution figure is shown next it will explain the percentage of RXLEVSUB for the bins in Jabryat drive test.

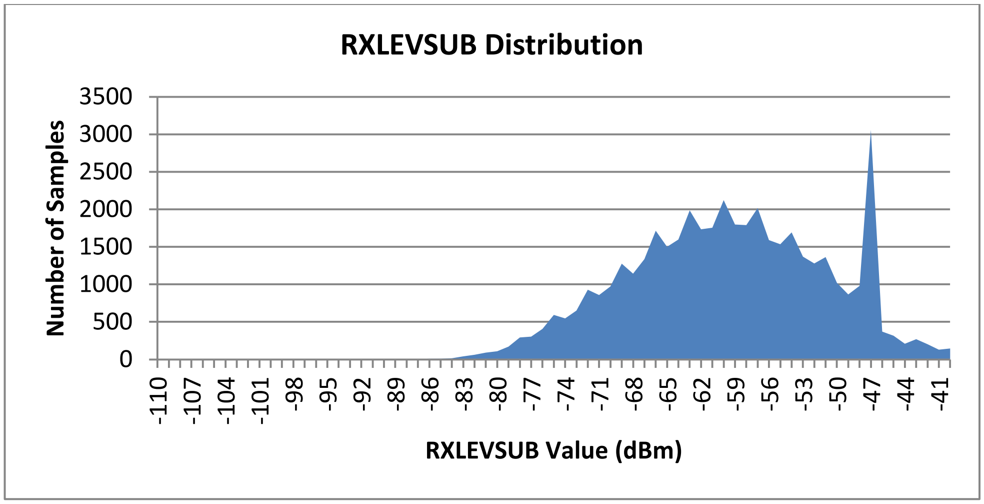

Figure 4.22: RXLEVSUB distribution for Jabryat area in August, 2010.

From the RXLEVSUB distribution, this is a good covered area. The average of RXLEVSUB in this area is 59.60 dBm and the standard deviation equals 8.64.
Here we comes to the RXQUALSUB distribution figure in which the RXQUALSUB values are shown with their percentage in Jabryat area drive test.

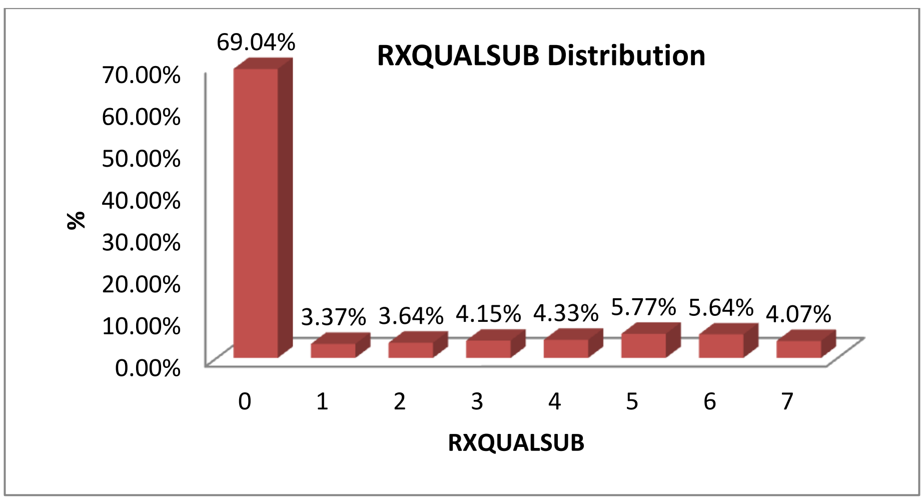

Figure 4.23: RXQUALSUB distribution for Jabryat area in August, 2010.

The best RXQUALSUB is dominant with about 69% of the samples. However the percentage of RXQUALSUB of 6 and 7 are 5.6% and 4% respectively.
The poor design table that classifies the problems with the percentage of each reason is shown next.

Cause	Percent
Interference	75.9%
Poor level	0.0%
Poor quality and poor level	0.1%
No dominance	12.8%
Interference and no dominance	11.1%
Poor level and no dominance	0.0%
Poor quality, poor level and no dominance	0.0%

Table 4.19: Poor design reasons with their percentage for Jabryat area in August, 2010.

Again, it is noted that 75.9% of the poor design are caused by interference and this a huge percent. The second issue is the no dominance. Here there is also issues caused by the poor coverage and hence the planned site JENI19 comes to solve these issues.

4.4 Conclusion

All the drive tests are collected by using Ericsson TEMS Investigation 8.1 Data Collection using two MSs, one for dedicated mode and the other is for scanning mode. Actix Analyzer and TEMS Investigation Route Analysis are then used to analyze these drive tests and to provide the coverage maps, coverage classes, distribution figures for RXLEVSUB and RXQUALSUB and design validation tables. Also, TEMS Route Analysis is used for analysis to provide us with coverage level distributions. The coverage level distribution for all over Jenien city shows us that about 8% of the collected samples lie in level 4 which is the worst level in both the RXLEVSUB and RXQUALSUB. By inspecting drives test of each area in Jenien city and the reasons for the poor performance, it is founded that interference is the major reason for poor performance at almost all parts of Jenien city. The second reason is the no dominance. Poor level is another reason that makes poor coverage performance.
Interference is a direct result of the bad frequency reuse that is currently used in Jawwal GSM network in Jenien city. Methodologies that will enhance the performance (improve quality and coverage) of Jawwal GSM network in Jenien city are explained in the next chapter 5.

Chapter 5

Optimization of Jawwal GSM Network in Jenien City

5.1 Introduction

The evaluation phase of the current GSM Jawwal network in Jenien city, which is done by performing KPIs collection and by drive test analysis for all over Jenien city, indicates that all areas in Jenien city suffer mainly from high level of interference resulting in poor RXQUALSUB and poor RXLEVSUB. After the evaluation phase (see Figure 1.6) which pointed out the main issues in the current GSM Jawwal network in Jenien city, the methodologies to solve these issues are then presented in the optimization phase addressed in this chapter.

The optimization process consists of two stages which are: First, manual optimization process which starts with capacity analysis and neighbor relation plan. It yields two outcomes which are new frequency plan for both BCCH and TCH frequencies, and new neighbor relation plan. Second, the optimization process using OSS optimization tools. At this stage, the outputs of the manual optimization process are fed to OSS optimization tools. The output of this phase is another frequency plan for BCCH and TCH frequencies with reduced interference. An enhanced neighbor relation plan with better handover performance is the other outcome of this stage. The details of the optimization process are shown in Figure 5.1.

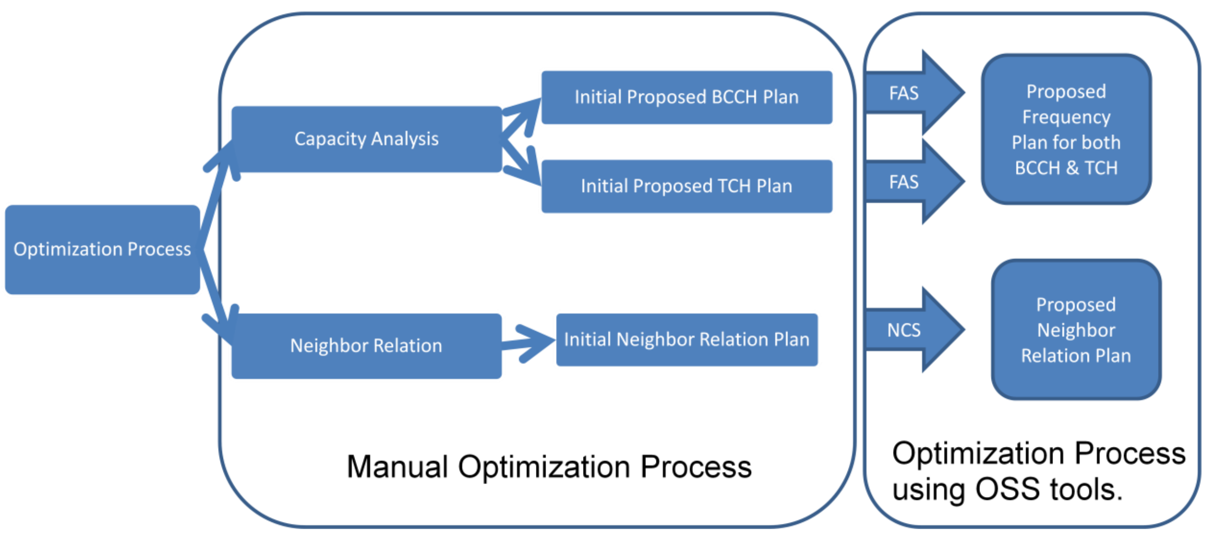

Figure 5.1: Optimization process with its two stages.

5.2 Manual Optimization Process

This process is started with capacity analysis and neighbor relation analysis. The capacity analysis is a study in which the peak carried traffic is determined for each cell in Jenien city. Then the exact number of needed traffic frequencies is calculated to handle that peak traffic for each cell. This will result in different frequency distributions between the BCCH and TCH frequencies. Neighbor relation study is then made by considering the geographical topology of Jenien city. The following rules are considered during this part of optimization process:

1. Never assign the same BCCH to two neighboring cells to avoid sever C/I.
2. Avoid assigning adjacent BCCH to neighboring cells to avoid C/A.
3. Avoid using the same MAIOs in the cells that are very close to each other.
4. Must use different HSN for each site. This is applicable since there are 63 HSNs and there is only 21 sites in Jenien City.
5. Try to minimize the number of neighbor relation as much as possible considering the geographical location of each cell. This will boost the handover success rate which will results in reduced TCH drop rate.

As a result of manual optimization process initial frequency plan is proposed. This initial frequency plan consists of BCCH and TCH frequency plans. The neighbor relation plan is another result for the manual optimization process. A detailed description for each step is discussed next.

5.2.1 Capacity analysis and peak carried traffic

Let us start by defining the term traffic which is a measure of the channel utilization or it is the average channel occupancy measured in Erlangs [1].
In GSM, system capacity depends on:

1. The number of traffic channels that is reserved for voice and/or data.
2. The Grade of Service (GoS) the subscribers are encountering in the system [1].

The traffic carried by a given cell depends on the number of traffic channels available and the amount of acceptable congestion which is (GoS). Erlang's B-table relates the number of traffic channels, GoS, and gives the offered traffic which is shown partially in Table 5.1 [25].
Suppose that there is a cell with 2 TRUs, the rule of thumb for assigning control channels is to assign control channels equals the number of TRUs. In our case, we need to assign 2 control channels one BCCH and one for call setups (one SDCCH). So, we have 2 TRUs * 8 Time Slots - 2 control channels =14 TCHs.
These 14 TCH are at full rate but it is common in Jawwal to activate Half Rate (HR) of 80%. 80% HR for each TCH is allowed since it is the perfect trade-off in terms of capacity and voice quality as tested in Jawwal system. The total TCH with 80% HR are now equals 14*0.8+14=25.2 TCHs . Let us adopt GoS of 2% (2% GoS is adopted by Jawwal and

commonly by the most of GSM operators). So, the traffic that can be offered is 17.5 Erlangs from Erlang B table (Table 5.1).

Erlang's B Table for GoS=2%	
No. Of TCH Channels	**Offered Traffic [E]**
1	0.02
2	0.22
3	0.60
4	1.09
5	1.66
6	2.28
7	2.94
8	3.63
9	4.34
10	5.08
11	5.84
12	6.61
13	7.40
14	8.20
15	9.01
16	9.83
17	10.66
18	11.49
19	12.33
20	13.18
21	14.04
22	14.90
23	15.76
24	16.63
25	17.50

Table 5.1: Erlang B table (partial view).

We know that 16 TCHs are currently used in Jenien city to support the high configuration of 18 TRUs per site. After new sites are introduced, the carried traffic for a given cell will be shared among the existing and the new introduced cells. This leads us to reduce the configuration for some cells in Jenien city and thus reduce the needed traffic channels. This will of course increase the BCCH ARFCNs which will result in less BCCH frequency reuse and then reduce interference.

Figure 5.3 shows the peak carried traffic by each cell in Jenien city. This is the peak carried traffic in Erlangs with resolution of hours. Peak traffic is the maximum traffic that is ever carried during a given period. This means that the worst case is taken into account and that gives more reliable design when speaking about carried traffic.

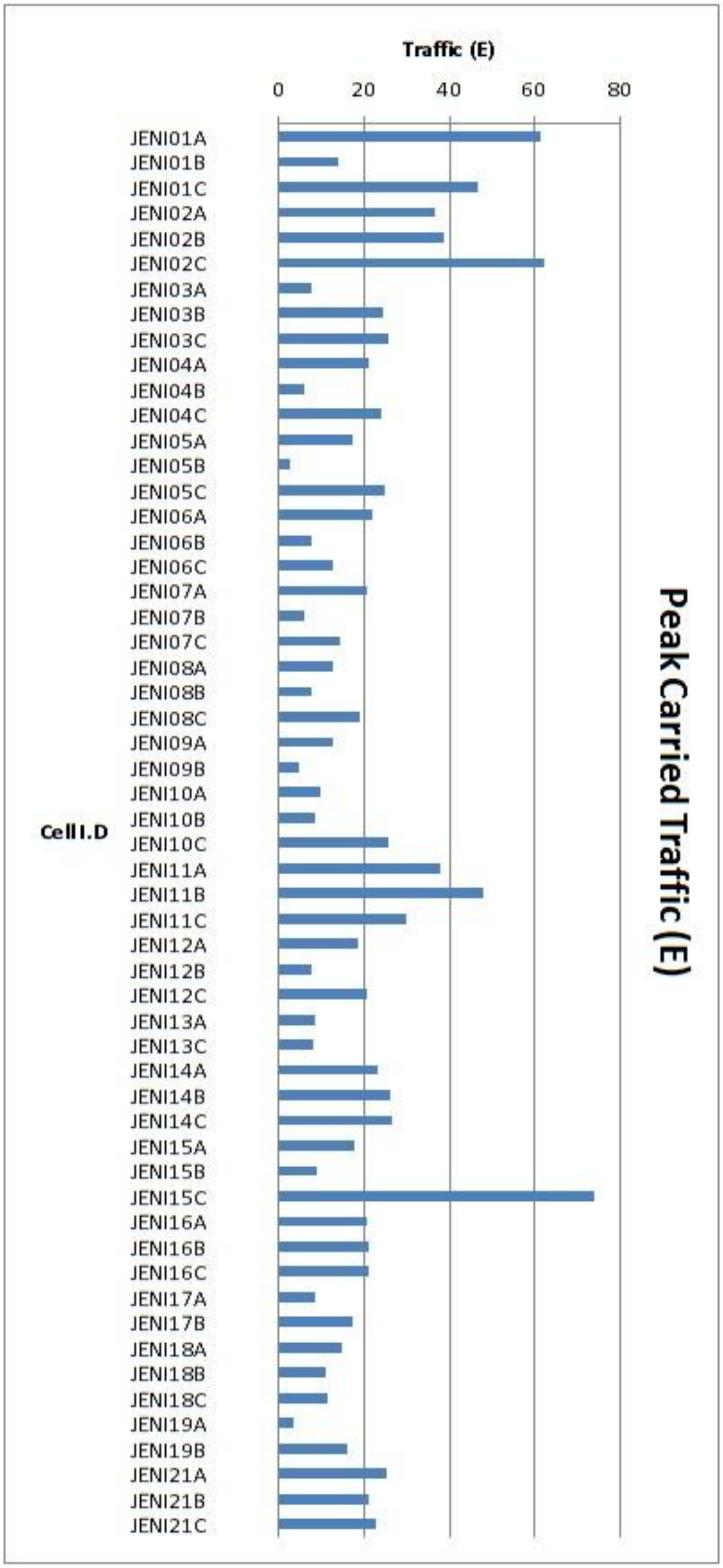

Figure 5.2: Peak carried traffic for Jenien city cells during November, 2010.

From Figure 5.2 it is noted that the cell JENI15C is the cell with the highest peak carried traffic. This cell carries about 74 Erlangs at the peak hour. Note that JENI15C serves a large area at central market in Jenien city. This cell carries that peak traffic at nearly 13:00 but it carries only 7 Erlangs at 21:00. This is the idea behind designing the capacity on the peak carried traffic rather that the average traffic.

Now, we knew the peak carried traffic by every cell in Jenien city. We also knew the number of traffic frequencies assigned to each cell. We can recalculate the required TRUs for each cell and hence the number of required frequencies. The offered traffic can be calculated from Erlang B table considering 80% HR. The required traffic frequencies is calculated from equation 2.3.

Cell I.D	Peak carried traffic (Erlang)	Current TRUs	Current Traffic Frequencies	Proposed TRUs	Proposed Traffic Frequencies	Proposed Total Channels	Proposed Total Channels with 80% HR	Offered Traffic (Erlang B table)
JENI01A	61.53	8	7	7	6	56	90	78.3
JENI01B	13.88	4	3	2	1	16	25.2	17.5
JENI01C	46.87	6	5	6	5	48	79.2	67.72

Table 5.2: Peak carried traffic, current configuration for cells of Jenien city vs. proposed configuration and offered traffic from Erlang B table, example JENI01.

Table 5.2 shows the new configuration for the site JENI01 and the corresponding offered traffic. It is noted that with the new configuration (i.e., 15 TRUs instead of 18 TRUs) the offered traffic still greater than the peak carried traffic. This corresponds to a reduction of 3 TRUs at site JENI01. Using 15 TRUs for JENI01 means that, we saved 3 TCH frequencies that can be re-used efficiently to enhance the frequency plan of the network.

Figure 5.3 shows the current peak carried traffic for each cell in Jenien city vs. the offered traffic form the Erlang B tables after adopting the new configurations of the TRUs and consequently the new configurations of the TCH frequencies.

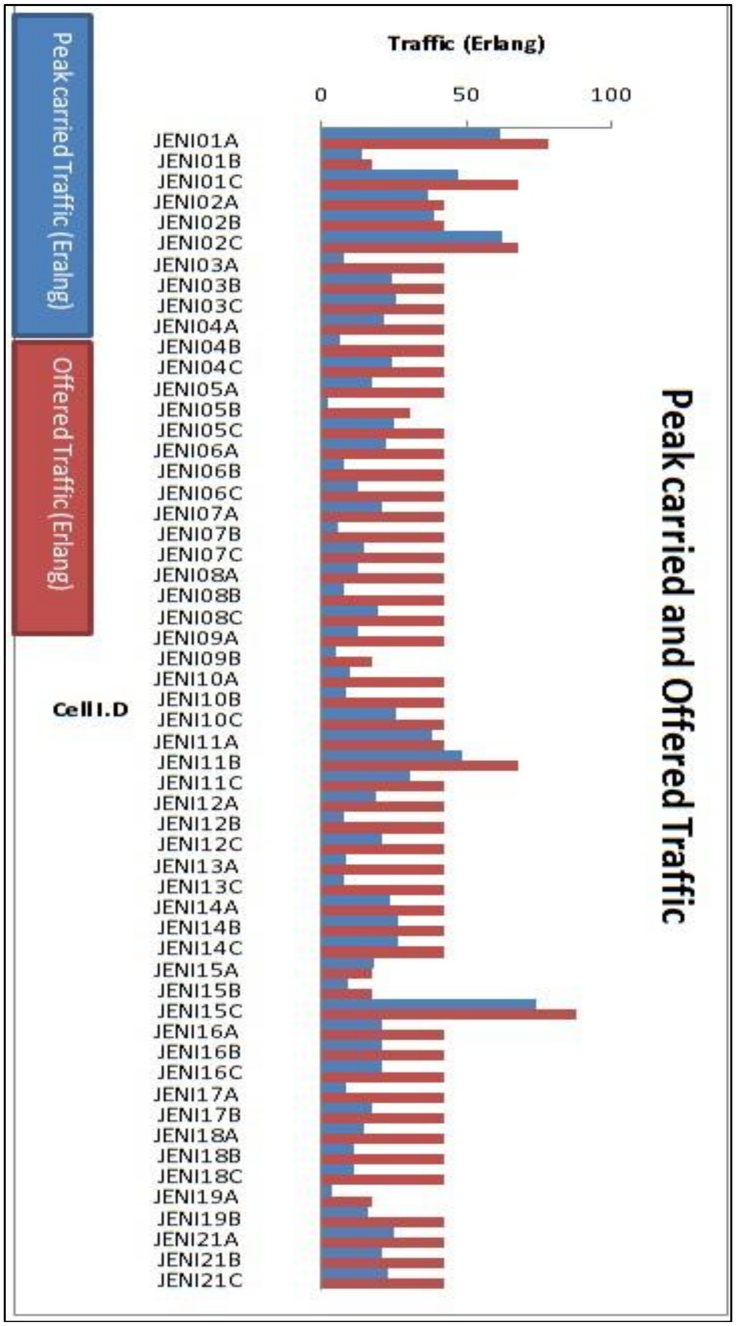

Figure 5.3: Peak carried traffic vs. offered traffic considering the new initial traffic frequency plan.

It is noted from the Figure 5.3 that the offered traffic from Erlang B tables is always greater or equal to the peak carried traffic. This adds safety margin to the new proposed design.

Figure 5.4 compares the current configured traffic frequencies with the proposed frequencies per site after reducing the number of TCH frequencies. It is noted that 15 TCH frequencies are currently configured for the sites JENI01 and JENI11, whereas only 12 TCH frequencies are required to carry the peak traffic . A reduction of TCH channels can also be made for site JENI02.

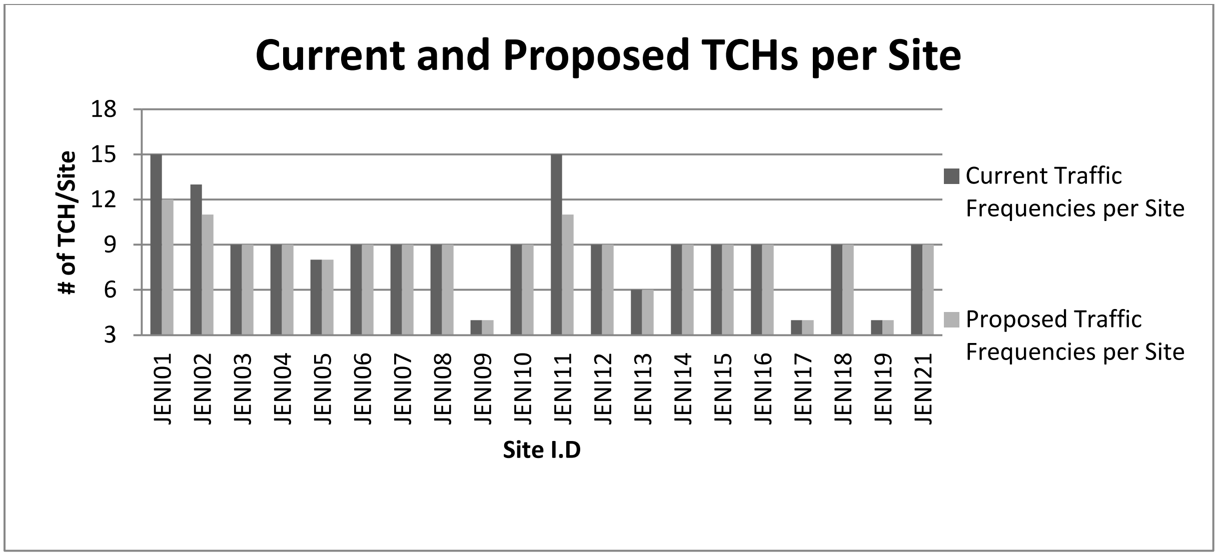

Figure 5.4: Current and proposed TCH frequencies per site in Jenien city.

From the above discussion it is noted that there is a trade-off between the system capacity and interference. Indeed, if we want to increase the capacity we must make a lot of frequency re-use and that also increase the interference. So, what we tried to make here is to find the point at which a low interference level is reached while making the cells capable of handling the peak traffic. This will be accomplished by taking frequencies from the traffic and assign them to the control channel. This is done without affecting the capacity of each cell.
From the above results it is noted that 12 ARFCNs will be used as BCCH and another 12 ARFCNs as TCHs. This gives a total of 24 ARFCNs that are available for Jawwal. This will reduce the interference since new fresh frequencies will be used for BCCH. This will lead us to the next section which is the new frequency plan for both BCCH and TCH.

5.2.2 Initial proposed BCCH and TCH frequency plans

Now we have 12 BCCH ARFCNs starting from 113 to 124. These 12 BCCHs will be distributed between the cells of Jenien city. Here, the manual optimization algorithms will be used for performing frequency plan which depends on the factors mentioned earlier. The main goal of this new initial frequency plan is to avoid assigning neighboring cells with the same BCCH. The manual optimization is started at the cells in the center of Jenien city and then spread out to the borders of Jenien city. Starting with the cell JENI01, the cells of this site are assigned to given BCCHs and its neighbor relations are listed. Depending on those neighbor relations, the nearby cells are assigned with different BCCHs and so on. This process is repeated till all the of Jawwal GSM cells in Jenien city are assigned BCCHs by taking into consideration the manual optimization criteria.
For the TCH frequencies, the issue is a little bit different. But, the ultimate goal is also to avoid assigning neighboring cells with the same TCH frequencies. However, it is hard to accomplish this as each cell will use 1 TCH frequencies at least.
Figure 5.5 and Figure 5.6 show the initial frequency plan for BCCH and TCH frequencies, respectively.

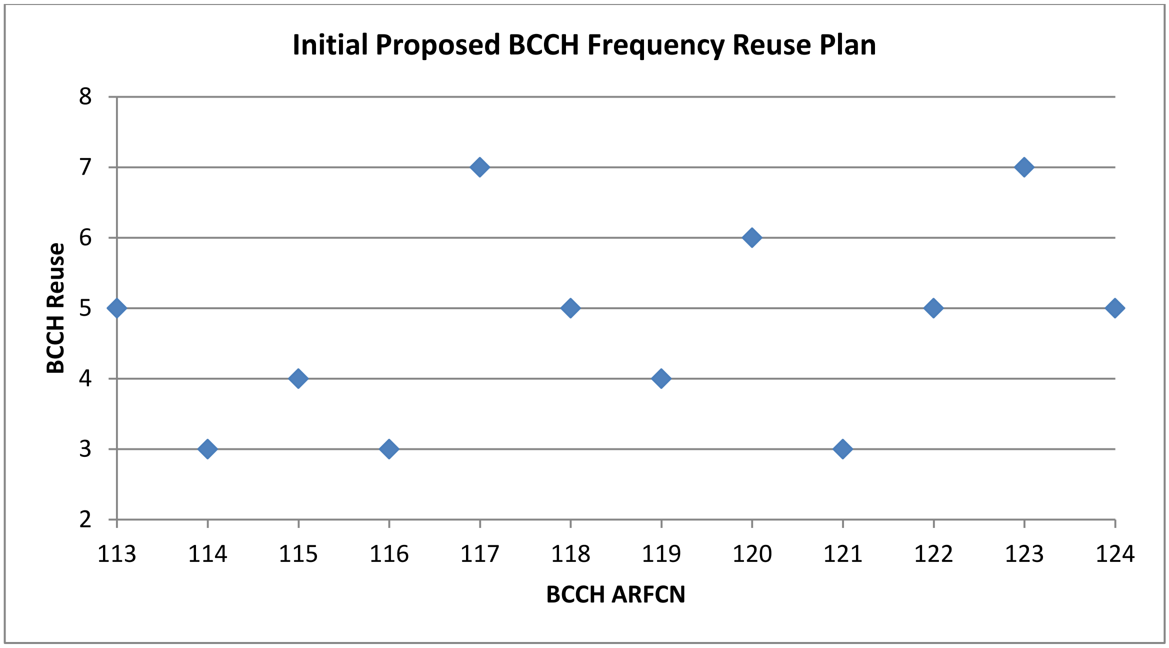

Figure 5.5: Initial proposed BCCH frequency reuse plan.

From Figure 5.5, it is noted that the BCCHs are less reused among Jawwal GSM cells as compared the previous situation of only 8 BCCHs. This results in less interference level on control channels.
The same thing applied for TCH frequencies, in which the new TCH frequency range (101 to 112) is reused to minimize the interference on the traffic carriers.

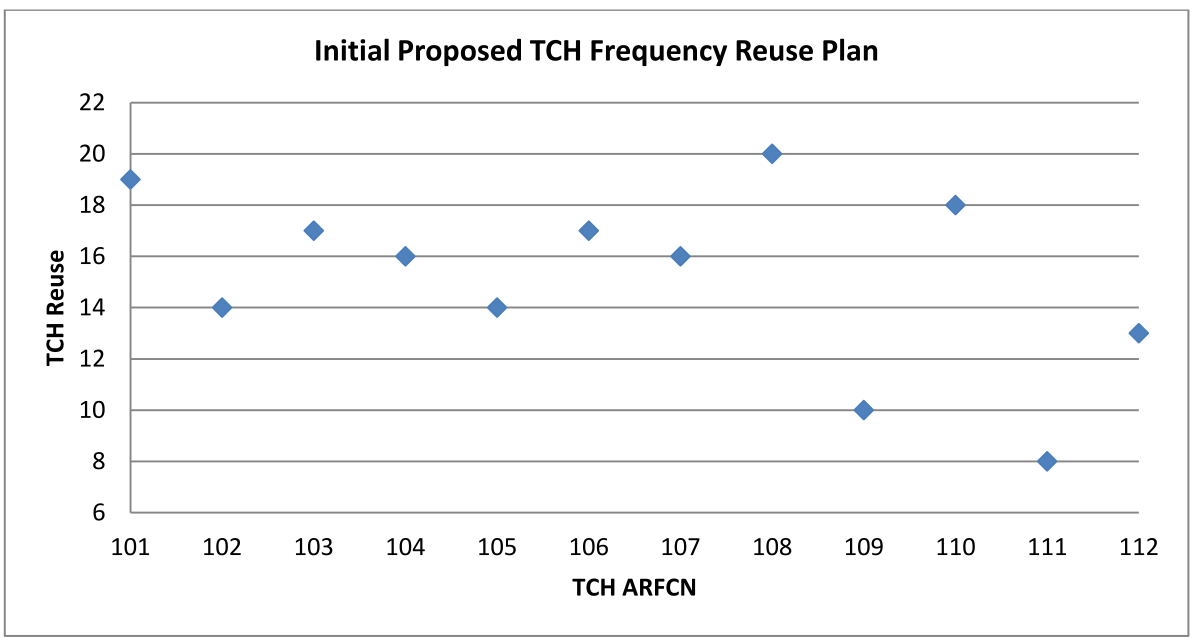

Figure 5.6: Proposed TCH frequency reuse plan.

5.2.3 Initial proposed neighbor relation plan

New neighbor relation plan must be developed depending on the geographical area and the cells location. The neighbor relation audit is very important in order to avoid the same BCCH for neighboring cells to minimize interference. Ericsson recommends that each cell should have neighbor relations between 6-15. This is for reducing the overhead for both the BSC and MS. The good neighbor relation plan is reflected by the good handover performance and also by the reduced TCH drop rate.

Figure 5.7 shows the proposed initial neighbor relation plan for Jawwal cells in Jenien city. This neighbor relation plan is developed by taking into consideration the geographical location for each cell and the subscribers mobility profile.

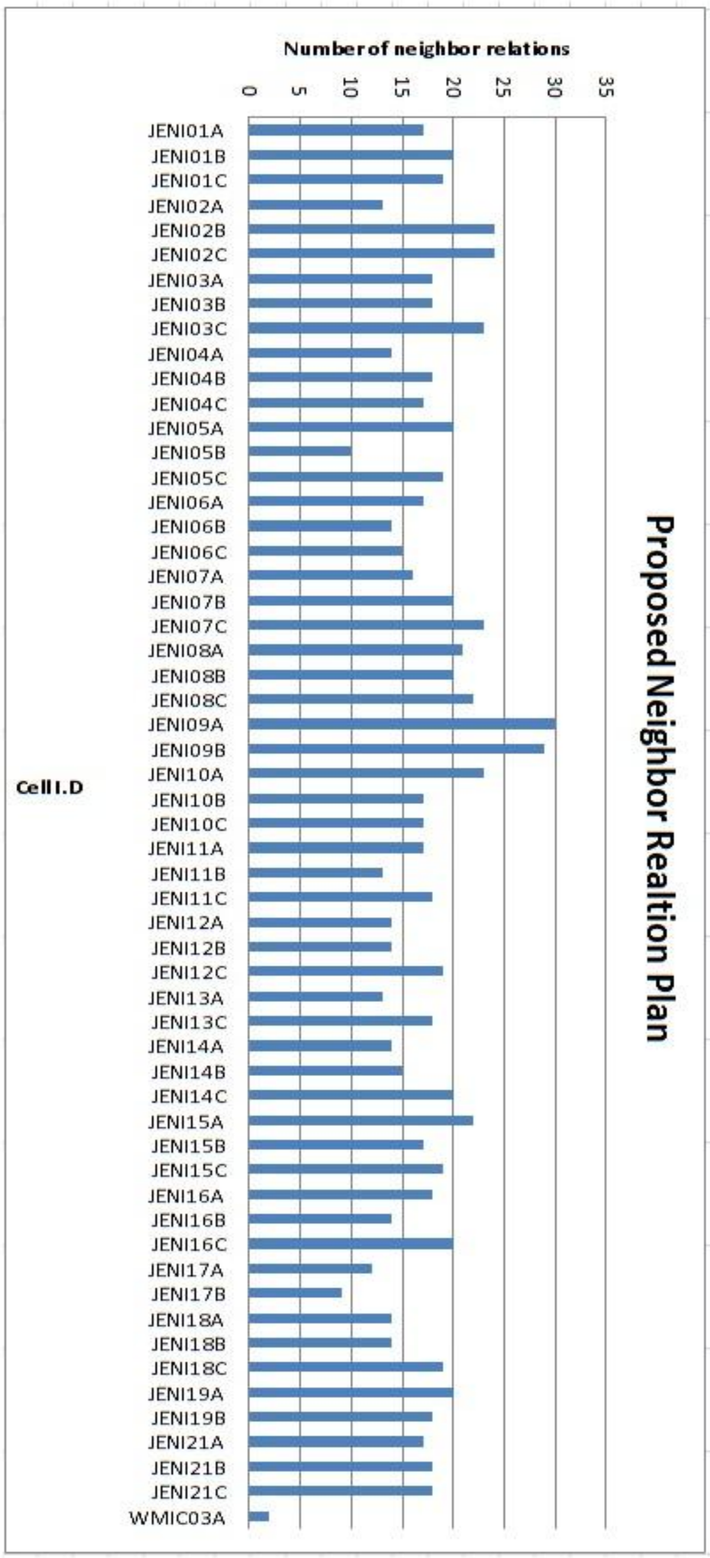

Figure 5.7: Proposed initial neighbor relation plan.

After new initial results are obtained, in terms of frequency plan and neighbor relations, the implementation process is the next step (Figure 1.5) which is the topic of the next section.

5.3 Implementation

Following the capacity analysis and the new distribution between the traffic and control channels which lead to initial proposed frequency plan for all the cells in Jenien city and new initial neighbor relation plan, the implementation of these initial plans is carried out. But, it is important to note that the above changes on frequency and neighbor relation will deeply impact the whole parameters of GSM network in Jenien city. The above plans will affect most of the configuration data for all the cells in Jenien city. The configuration data includes the new BCCH, TCH, MAIO, HSN, DCHNO and neighbor relations. At this step, all the new proposed configuration data will be implemented for the cells of Jenien city. This process is done from the BSC side and each parameter is changed by using the suitable command. During the implementation process, each cell state will be changed to halted so the user can not access that specific cell during the implementation. This process in done late at night to avoid customer's dissatisfaction. This process is started on 27.02.2011 at 21:00 and finished on 28.02.2011 at 05:15 by the great BSS team in Jawwal.

5.4 Evaluation, First Impression

After the implementation, the natural step is to evaluate the behavior of the new configured GSM network in Jenien city.

Here, this step comes to find the initial results from the new frequency plan. Figure 5.8 shows the TCH drop rate, carried traffic and SDCCH drop rate with quarter hour resolution to identify any dramatic results.

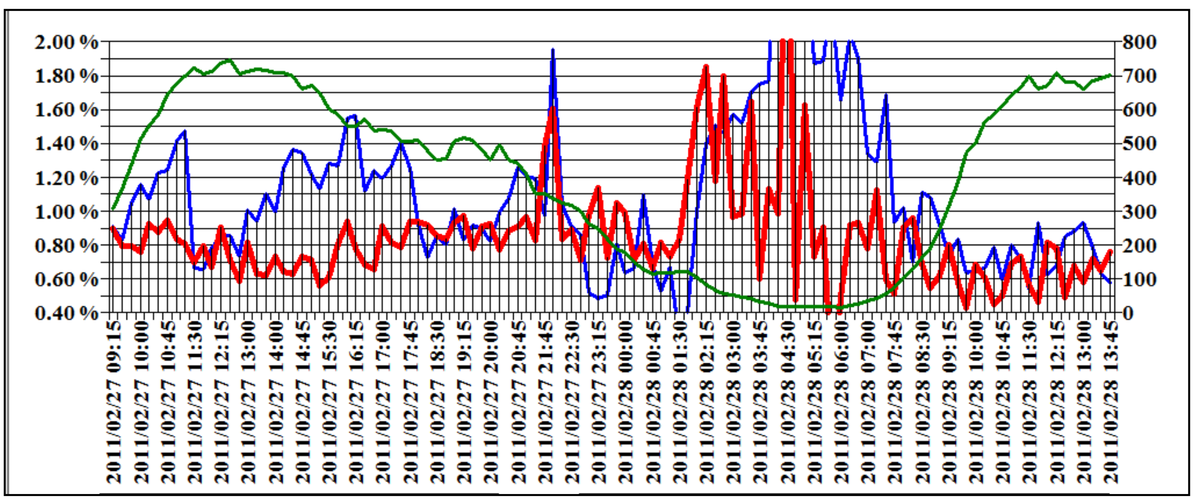

Figure 5.8: Traffic drop (red line), carried traffic in (E) (green line) and SDCCH drop (blue line) during and after implementing the new configuration data for Jenien city with quarter hour resolution.

Note that the implementation process is finished on 28.02.2011 at 05:15. It is obvious from Figure 5.8 that this time makes a lot of variation in the behavior of the network. After that time, it can be noticed that the traffic drop rate is decreased and then increased to values less than those values before the reconfiguration. From Figure 5.8, it can be also noticed that there is a little bit enhancement in both TCH drop and SDCCH drop rates. As better performance is obtained from the new configured network, continuing the optimization process is the topic of the next section using OSS tools.

5.5 Optimization Process Using OSS Tools

There are many Radio Network Optimization tools (RNO) used in optimizing and enhancing the performance of the GSM cells. There are tools with different usages; some tools are used to find a better BCCH and TCH frequencies for an active cell. Other tools are used to identify the missing/extra neighbor relations and other used to evaluate the RXQUALSUB, TA and path loss for active cells. A detailed description for the most three important tools are given next:

1. Frequency Allocation Support (FAS):

Every cell in a GSM system is configured with idle list that contains the range of ARFCNs used as BCCH or DCHNO for that cell. FAS simply measures the interference on every configured ARFCN on that idle list and also tells us what are the names of the interfering cells. FAS is used to find better frequency allocation for a given cell, to introduce a new cell to the GSM network or even to monitor the interference level on the whole GSM network. Interfered TCH frequency leads to bad speech quality and higher drop rate. Interfered BCCH frequency also leads to poor handover statistics and BSIC decoding problems. The complexity of finding and solving this problem increases with the number of frequencies assigned per cell. Also FAS can be used to detect external interference which may come from other networks, cordless phones, surveillance systems, military equipment, etc. The interference level in GSM networks has to be kept to minimum in order to use the frequency spectrum in an efficient way, and to increase the capacity of the network. The speech quality and the amount of dropped calls are directly affected by the interference level.

FAS is an optional feature aims at relieving the user from the burden of frequency optimization. By monitoring the UL and DL interference environment in the network, FAS can find bad frequency allocations, both for BCCH and TCH carriers. The user can order FAS to perform recordings on up to 150 frequencies in at least 2000 cells handled by one OSS. After the recording is completed, the result values are reported to OSS where they are processed and presented to the user in reports and in geographical maps.

The uplink measurements are made by all TRUs in all cells that are included in the recording. A sample of the uplink interference is collected at least every 15th second on every frequency that was chosen before the start of the recording. The result that is collected by FAS at the end of the recording consists of three values for every frequency in every cell; a median value, a percentile and the number of samples.

The downlink measurements are based on measurements made by the MS. According to the GSM specifications, the MS measures on every frequency that is specified in the BCCH Allocation list (BA List) which is a list of frequencies transmitted by every cell. Six of the strongest surrounding cells with BCCH frequency in the BA list are then reported back to the BTS approximately twice every second (480 msec.). The report with the six cells is called the

Measurement Report (MR). The information that is included in the MR for the six surrounding cells are: Signal strength, BCCH frequency and BSIC. The last two are used to identify which cell has been measured. FAS is able to modify the BA list so that frequencies normally not included in the BA list can be measured. For every MR, the signal strength of the reported cells are compared with the signal strength of the serving cell, to see if there is any potential interference among the cells.

2. Neighbour Cell Support (NCS):

NCS is used to find missing neighbouring cell relation if there is any. Since missing neighbour relation result in more dropped calls and bad quality for the users. NCS is also used to find unnecessary neighbouring cell relations. Having unnecessary neighbours in the BA list makes the measurement less accurate. The problem of having missing neighbour relation is more critical than having extra defined neighbour relations. As a rule of thumb about 16-20 frequencies in the active BA list are recommended, but some cells require more than that since they cover a large area and need to have handover relations to many other cells. Also NCS can be used to find neighbours to a cell that is newly introduced to the GSM system. The main benefits of NCS are:

a) Based on measurements in the live network, the data from the calls made by the users in the network.
b) It has an intelligent analysis that gives recommendation on additions and removals of neighboring cell relations.
c) Offer faster analysis and smoother implementation.
d) Reduce the amount of drive tests which is a time consuming process.

NCS uses the BAR function. This means that the BA lists in the cells are temporarily modified so that the MS measures also on frequencies not normally in the BA list. This applications help you to find missing neighbors and to remove unnecessary neighbors. To find which neighboring cell relations to add, the result from the BAR-recording is used. To find which neighboring cell relations to remove, handover statistics is used. NCS present the recorded measurements and statistics in several reports, which the user can study in order to find which neighboring cells relations that should be removed and added.

3. Measuring Recording Report (MRR):

The MRR application can be used for supervision of the network performance, troubleshooting of the network and comparison of the network performance. MRR is a feature in the OSS recordings that can be defined scheduled, ended, stored and processed in OSS. The operator can generate a large number of reports that can be used to analyse each recording and make comparisons. MRR is based on a function in the BSC, where it is possible to initiate and to end a recording by command. All data are recorded initially by the BSC and stored in a binary file that can be output directly or forwarded to OSS for further processing. The radio characteristics can be recorded for one or more cell sets simultaneously by initiating one or more recordings. A cell set can comprise one or more cells.

MRR function collects information about serving cell in the uplink and downlink directions. When defining a recording, it is possible to set thresholds for quality (RXQUALSUB), signal strength (RXLEVSUB) and timing advance (TA). MRR gives information about the statistical distributions for a number of radio characteristics. These distributions can be displayed in histograms. To verify changes in the network we have the comparison reports and the trend report.

MRR can be used for network supervision. Recordings can be scheduled in advance and repeated daily, weekly or every two weeks. In order to be of statistical significance, measurements have to be made over many cells and repeated many times on different days and in different weeks. Statistical calculations are performed in OSS each time a new report is to be viewed. The preferences for statistical calculation can be modified in the appropriate window. The available statistics are as follows:

a) MRR provides us with overview histogram which is used to show the distribution of one or multiple radio characteristic for all cells or for a subset of cells included in a recording result.
b) The MRR overview histogram is mainly a management report, used to get an overview of network performance. It can be used to compare different regions or different time frames from the aspect of example quality. The histograms show the distribution of one radio characteristics at a time.

After these RNO tools are used to optimize the performance of GSM cell of Jenien city. Some differences from the initial proposed frequency plan and from the initial proposed neighbor relation audit exist. These differences are implemented to the live network again and the performance is monitored again. From here in and after, we start to discuss the final frequency plan for all the cells, neighbor relation plan and other important parameters that give the better performance than the original one.

5.5.1 Proposed BCCH and TCH frequency plan using FAS

During the period of this research, new sites are introduced to the Jawwal GSM network in Jenien City to cure the issues of poor coverage, no dominance, congestion and to enhance the QoS. Table 5.3, shows the updated technical information about Jawwal GSM network in Jenien city.

According to table 5.3, it is noted that the number of cells in Jenien city is increased to 75 and the BCCHs are increased to 12. This increase in the number of BCCH will reduce the interference level on the BCCH.

Active Sites in Jenien City	JENI01, JENI02, JENI03, JENI04, JENI05 JENI06, JENI07, JENI08, JENI09, JENI10 JENI11, JENI12, JENI13, JENI14, JENI15 JENI16, JENI17, JENI18, JENI19, JENI20 JENI21, JENI24, JENI26, JENI27, JMIC03 JMIC06, WMIC03.
Total number of sites	27 Sites
Total number of cells	75 cells
Total number of BCCHs	12 ARFCN
Total number of TCHs	12 ARFCN
Total number of TRUs	269 TRUs
Serving BSC	BSC08
Serving MSC	MSC03

Table 5.3: Updated Technical information about current GSM network in Jenien city till the end of October, 2011.

Here, FAS is used to find better BCCH and TCH frequencies for all Jawwal GSM cells in Jenien city. FAS reports the interference on the configured idle frequencies list. So, we assign each cell the BCCH and TCH with lowest interference.

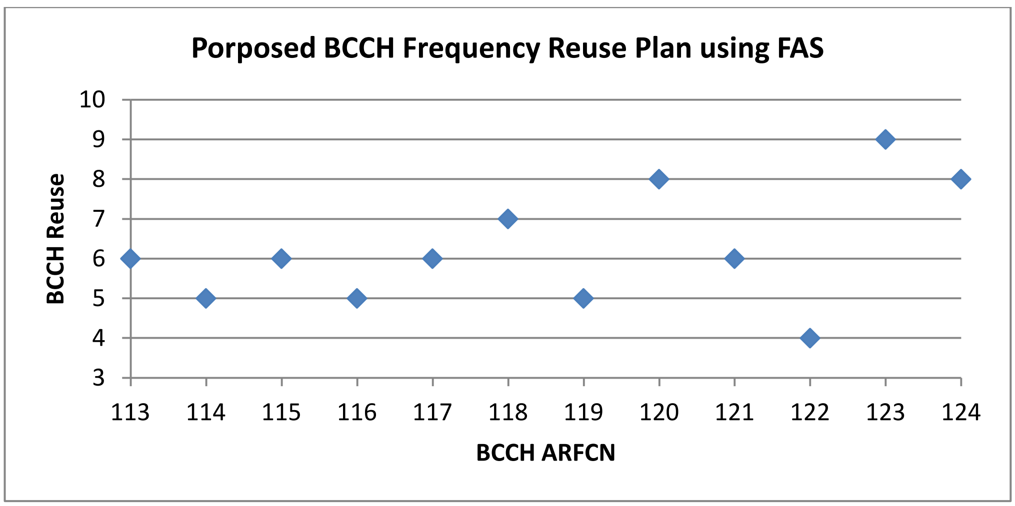

Figure 5.9: Proposed BCCH frequency reuse plan for Jawwal GSM cells in Jenien city using FAS.

The TCH frequencies also are re-planned using FAS in such a way that each frequency experience the least interference.

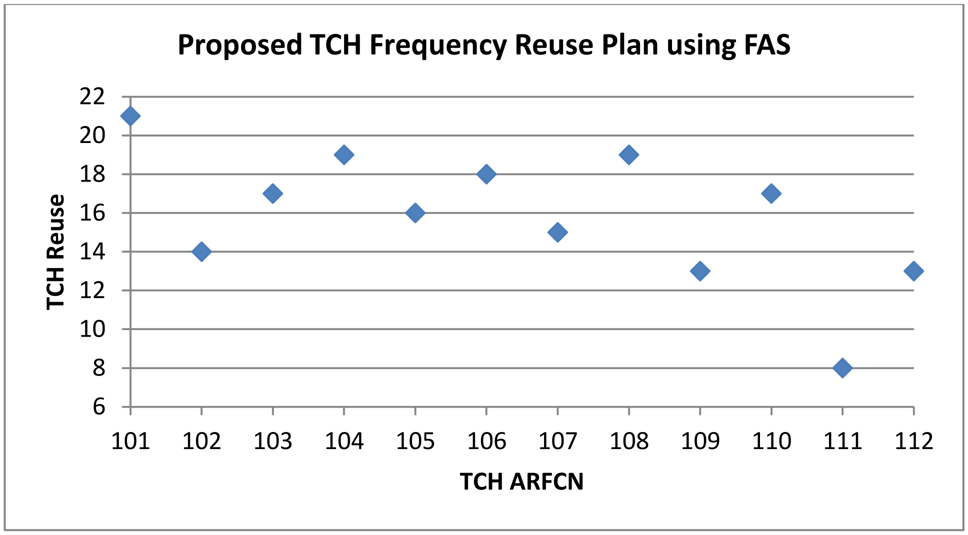

Figure 5.10: Proposed TCH frequency reuse plan of Jawwal GSM cells in Jenien city using FAS.

Figure 5.9 and Figure 5.10 show how the BCCH and TCH frequencies are distributed among the cells of Jenien city, respectively. It must be taken into account that at this stage, that each GSM cell in Jenien city is assigned its BCCH and TCH frequency with the least interference. This comes from the fact that the manual optimization phase is firstly adopted to select the BCCH and TCH for each cell that is unique for that cell from its neighbors. Also, this is followed by using FAS for optimizing the BCCH and TCH frequency. These two steps guarantee that this is the best BCCH and TCH frequency for that cell with the lowest possible interference.

Another critical parameter when speaking about the TCHs is the HSN. HSN is the parameter used to manipulate the traffic channels in pseudo random way. This reduces the possibility of having the same traffic channels collision at the same time which in turn reduces the interference. Table 5.4, shows the proposed HSN distribution of the sites in Jenien City. Here we proposed that each site has its unique HSN to reduce the interference on the TCHs for all the sites in Jenien city.

Site I.D	HSN	Site I.D	HSN	Site I.D	HSN
JENI01	1	JENI10	19	JENI19	50
JENI02	35	JENI11	26	JENI20	57
JENI03	7	JENI12	27	JENI21	18
JENI04	10	JENI13	61	JENI24	5
JENI05	43	JENI14	55	JENI26	36
JENI06	40	JENI15	9	JENI27	3
JENI07	45	JENI16	12	JMIC03	13
JENI08	31	JENI17	37	JMIC06	44
JENI09	22	JENI18	54	WMIC03	30

Table 5.4: Proposed HSN for the Jawwal GSM sites in Jenien City.

From the above discussion of capacity analysis and ARFCN redistribution, 12 ARFCNs will be used to carry the generated traffic from Jenien city. The GSM cell of Jenien city will be configured with the following proposed TRUs.

Cell I.D	Proposed TRUs	Cell I.D	Proposed TRUs	Cell I.D	Proposed TRUs
JENI01A	7	JENI09B	2	JENI18C	4
JENI01B	2	JENI10A	4	JENI19A	4
JENI01C	6	JENI10B	4	JENI19B	2
JENI02A	4	JENI10C	4	JENI20A	2
JENI02B	4	JENI11A	4	JENI20B	2
JENI02C	6	JENI11B	6	JENI20C	2
JENI03A	4	JENI11C	4	JENI21A	4
JENI03B	4	JENI12A	4	JENI21B	4
JENI03C	4	JENI12B	4	JENI21C	4
JENI04A	4	JENI12C	4	JENI24A	2
JENI04B	4	JENI13A	4	JENI24B	2
JENI04C	4	JENI13C	4	JENI24C	2
JENI05A	4	JENI14A	4	JENI26A	2
JENI05B	4	JENI14B	4	JENI26B	2
JENI05C	4	JENI14C	4	JENI26C	2
JENI06A	4	JENI15A	2	JENI27A	2
JENI06B	4	JENI15B	2	JENI27B	2
JENI06C	4	JENI15C	8	JENI27C	2
JENI07A	4	JENI16A	4	JMIC03A	2
JENI07B	4	JENI16B	4	JMIC03B	2
JENI07C	4	JENI16C	4	JMIC03C	2
JENI08A	4	JENI17A	2	JMIC06A	2
JENI08B	4	JENI17B	4	JMIC06B	2
JENI08C	4	JENI18A	4	JMIC06C	2
JENI09A	4	JENI18B	4	WMIC03A	4

Table 5.5: Proposed TRU configuration for Jawwal GSM network in Jenien city.

Table 5.5 shows the proposed TRU configuration for each cell in Jenien city after adopting the new plans for BCCH and TCH. From this table, it is noted that JENI01 was configured with 3 cells and with configuration of (8,4,6) TRUs, in this case 15 TCHs are used. Now the site is configured with 3 cells with (7,2,6). Now only 12 TCHs are used. This adds 3 form the TCHs to the BCCHs.

5.5.2 Proposed neighbor relations plan using NCS

After the initial neighbor relation plan is developed, which depend on the prior knowledge of the geographical information in Jenien city. This neighbor relation plan needs to be fine tuned and that is done by NCS as explained earlier. The new proposed neighbor relation plan is shown in Figure 5.11.

At the start of the work as reported in chapter 2 in Figure 2.2, the average number of neighbor relations was 18.64 considering that a total of 57 cells were existed. Now after finishing all the optimization process the average number of neighbor relation is 17.28 even when the number of cells now is 75 cells. This of course will improve the performance of handover statistics and will reduce the load on both MS and BSC. Thus, it will reduce the TCH drop rate for the overall Jawwal GSM cells in Jenien city.

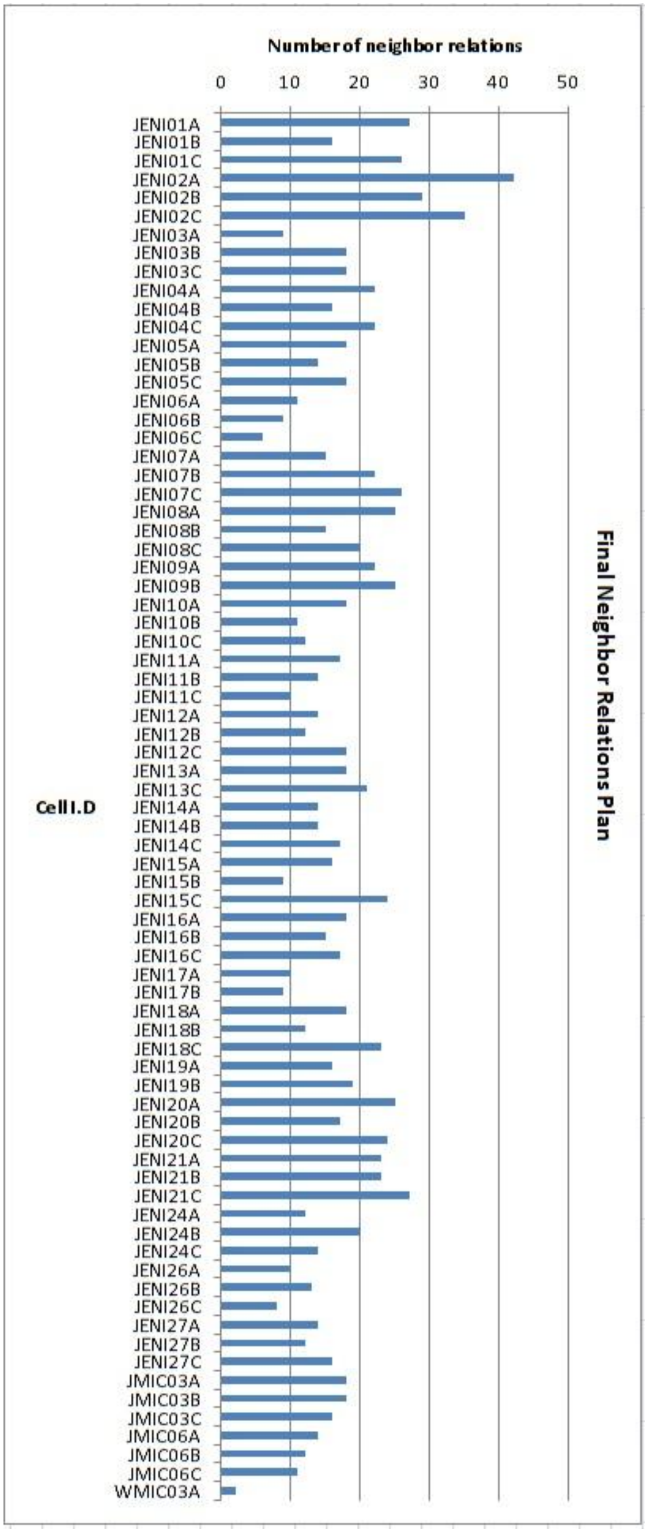

Figure 5.11: Proposed neighbor relations plan for Jawwal GSM cells in Jenien City using NCS.

5.6 Conclusion

This chapter comes to discuss the optimization process conducted in Jenien city in order to enhance the performance of Jawwal GSM network. The optimization process is classified into two stages. Stage one, is the manual optimization process. The manual optimization process includes capacity analysis from which initial BCCH and TCH frequency plans are produced. Also, it includes neighbor relations plan which produces initial neighbor relations plan for all the GSM cells in Jenien city. The outputs of the first stage are integrated to Jawwal GSM system in Jenien city. This step is followed by an evaluation phase from which better results are achieved in comparison with the previous performance. The two outcomes of the first stage are the inputs of the second stage which is the optimization process using OSS tools. This step comes to fine tune the initial plans to achieve the best possible performance. The second stage develop proposal for BCCH and TCH frequency plans. Also, it develops proposed neighbor relation plan. Those proposed BCCH and TCH frequency plans with the proposed neighbor relation plan are also integrated to Jawwal GSM system in Jenien city.

It is the time now for final evaluation and comparative study between the performance of Jawwal GSM system in Jenien city before and after the enhancement takes place. This comparative study will be executed by using KPIs with concentration on the TCH drop rate . The drive test is the second tool that will be used to compare the performance of the GSM system. This topic will be discussed is the next chapter.

Chapter 6

Comparative Study

6.1 Introduction

In this chapter, a comparative study between the performance of Jawwal GSM network in Jenien city before and after the enhancement process will take place. This comparative study will be executed by using the two previous approaches which are KPIs and drive tests. First, the KPIs of the new performance are collected after finishing the enhancing phase in Jenien city. These KPIs are denoted as KPIs in October, 2011. These KPIs are compared with those collected before the work started in Jenien city and they are denoted as KPIs in November, 2010. Second, Jenien city is drive tested again in October, 2011. This new drive test is conducted via the same drive test tools, at about the same time of the previous year. In addition, it is conducted across same areas in Jenien city as before. This is essential for fair comparison. The results of the drive test analysis are then compared with the old ones.

Note that in this research, we targeted the following points to be improved: First, to reduce the TCH drop rate for Jawwal GSM cells in Jenien city . Second, to reduce the percentage of the samples in level 4 and to increase the percentage of level 1 or level 2 of the drive test analysis.

Here, we will start by the comparative study using the KPIs. The effects of the enhancement that is carried out for the GSM network on the KPIs will be shown. The worst performing cells are then introduced again. After that the drive test analysis is introduced. The percentage of coverage classes per each area are then presented. This is followed by illustrating the RXLEVSUB and RXQUALSUB distributions. Finally, the design validation tables are introduced to find the poor design reasons.

6.2 Comparative Study Using KPIs

After the enhancing Jawwal GSM network in Jenien city, another round of KPIs are collected. The focus will be on the TCH drop rate which is the most important KPI. In addition, the worst performing cells for each KPI will be listed.

6.2.1 TCH drop rate

Figure 6.1 demonstrates the TCH drop rate in October, 2011.

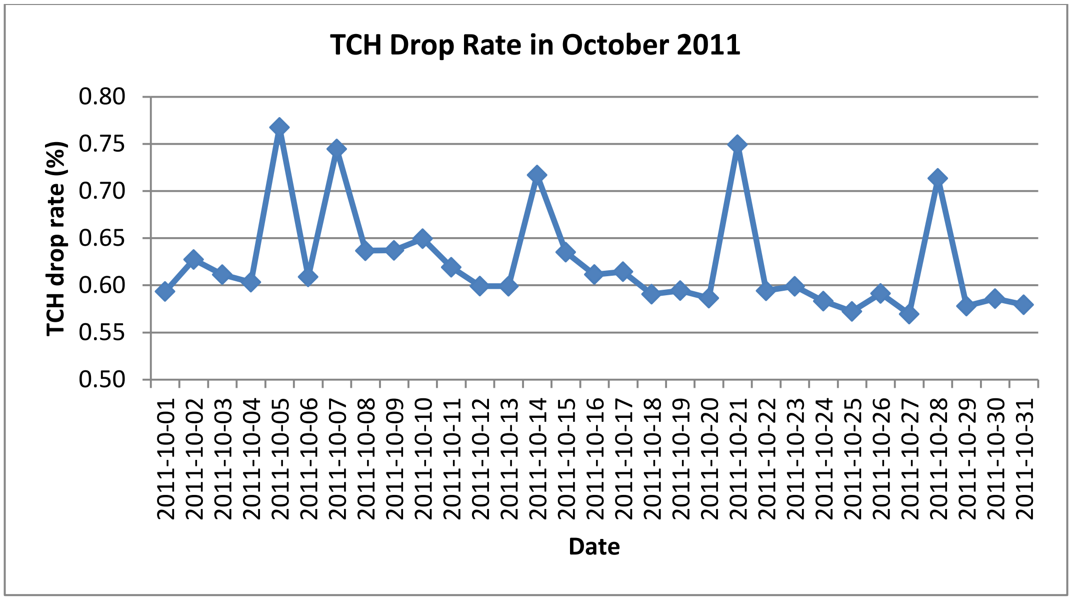

Figure 6.1: TCH drop rate for Jenien city cell set in October, 2011.

From Figure 6.1, it is noted that there is a significant decrease in the drop rate in the cells in Jenien city in October, 2011. The TCH drop rate is now 0.62% in average compared to 0.745% before this research is conducted. The decrease in the TCH drop rate here is about 16%, and it is worth it to mention that such a decrease in the TCH drop rate of alive network is hard to be obtained.

Now we can take a look at Figure 6.2 which shows the TCH drop reasons for the cells in Jenien city in October, 2011.

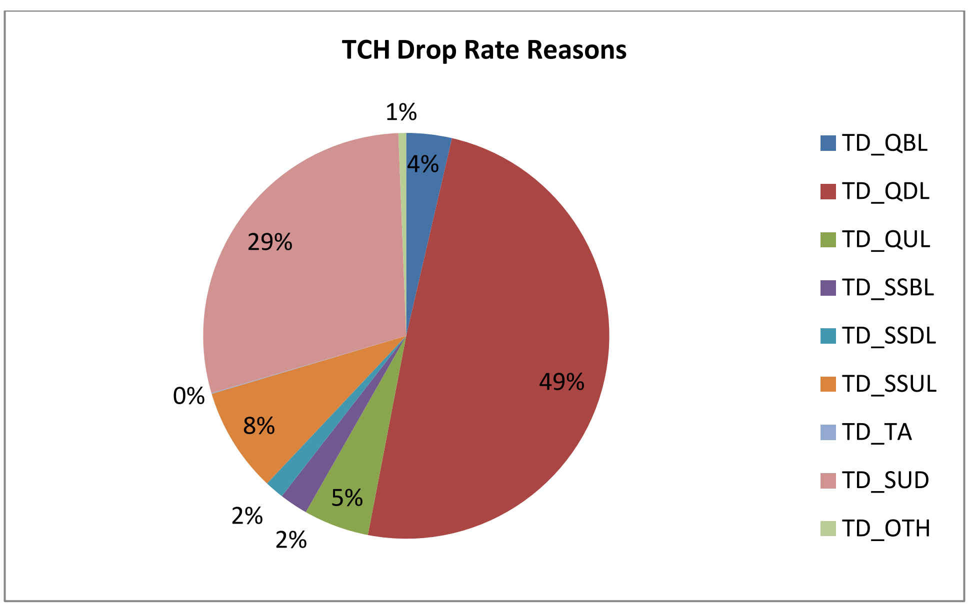

Figure 6.2: TCH drop rate reason for Jenien city cell set in October, 2011.

From Figure 6.2 it is noted that the main TCH drop reason is the TD_QDL which equals now to 49%, while was 54% during November, 2010 (see Figure 3.2). This means that the TCH drop rate due to quality in the DL is now lowered after applying the changes on the GSM network in Jenien city. Thus, the interference level on the BCCH carriers is reduced.

6.2.2 SDCCH drop rate and SDCCH congestion

SDCCH drop rate and SDCCH congestion KPIs are illustrated in Figure 6.3. From which it is obvious that there is approximately no congestion on the SDCCHs. This comes from the fact of correct dimensioning of the SDCCHs when carrying out capacity analysis. The SDCCH drop rate is now with average of 1.06% compared with 1.14% with the previous configuration.

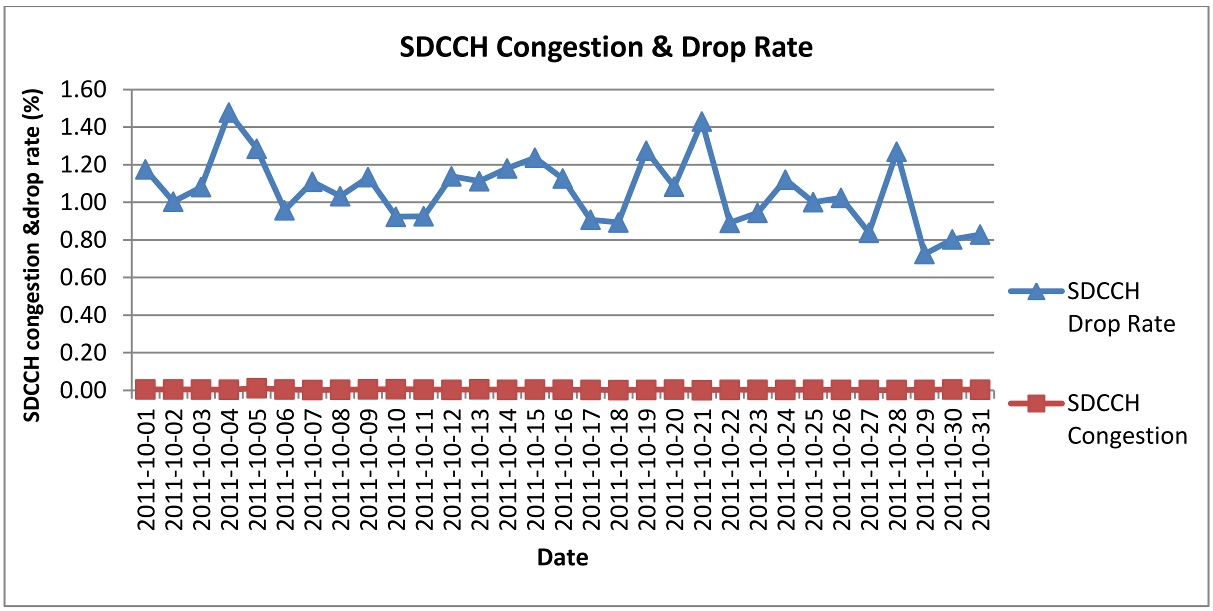

Figure 6.3: SDCCH drop rate and SDCCH congestion for Jenien city cell set in October, 2011.

Now let us move to the reasons that are responsible of making this SDCCH drop rate which are summarized in Figure 6.4.

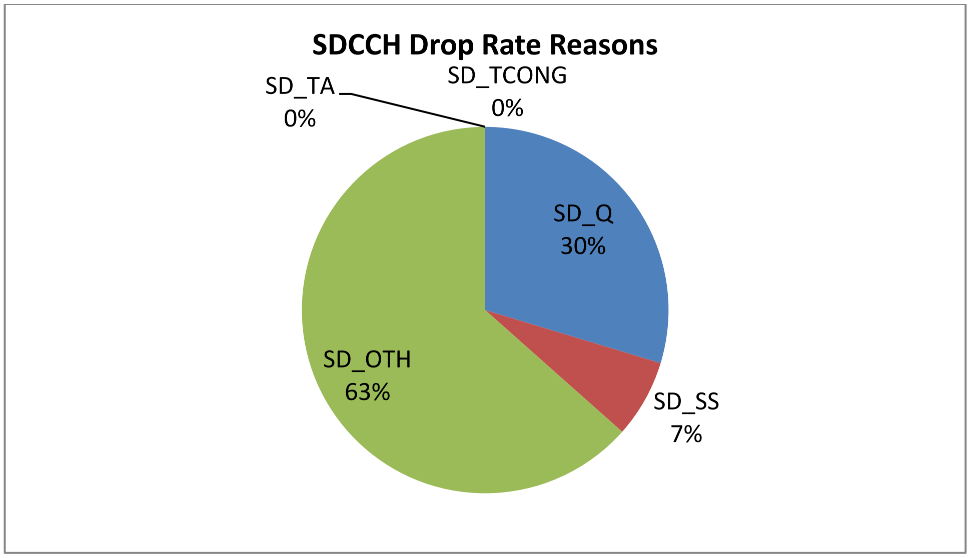

Figure 6.4: SDCCH drop reasons for Jenien city cell set in October, 2011.

When comparing Figure 6.4 and Figure 3.4, we note that SDCCH drop rate due to quality is lowered from 31.7% to 30%. The SDCCH drop due to others still at the top of the reasons with more than 60%.

6.2.3 TCH congestion and subscriber perceived TCH congestion

After identifying the congested cells in Jenien city and noting that most of these congested cells serve the center of Jenien city, we decided to build new sites inside the city center. These sites are capacity sites and offer the users with the needed capacity to reduce the already congested cells. These cells are with very limited coverage so they are called Micro sites instead of Macro cites. So, their names start with JMIC which stands for Jenien Micro. Figure 6.5 shows the cells with TCH congestion and subscriber perceived TCH congestion. Note that the new micro site JMIC03 is now the only one congested. To cure this issue another micro site is placed and operated named JMIC06. If you compare Figure 6.5 and Figure 3.5, you can note that the cells JENI14C and JENI02C are not congested since the new integrated micro site JMIC03 and JMIC06 serves the same area.

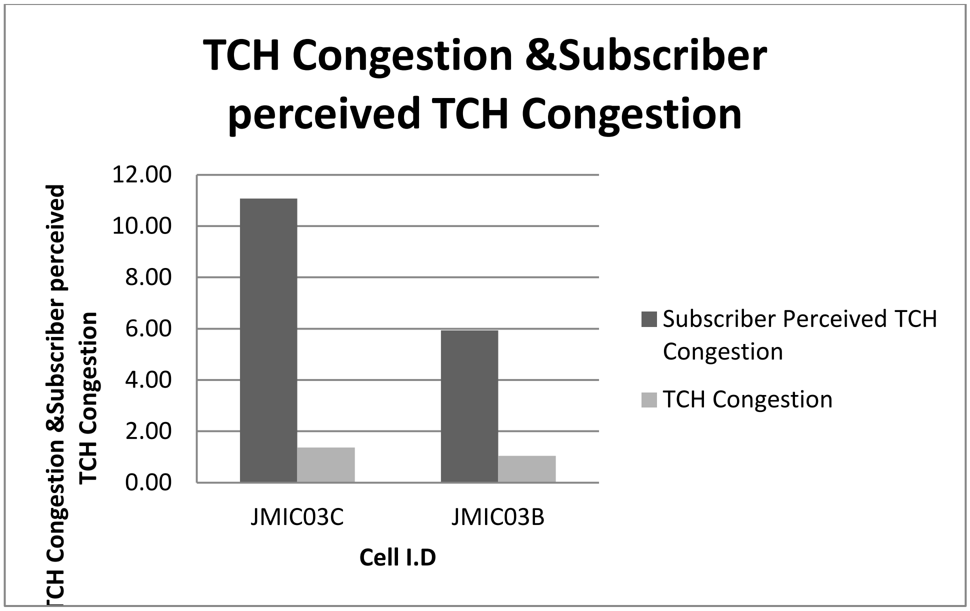

Figure 6.5: Cells in Jenien city with TCH congestion and subscriber perceived TCH congestion or both in October, 2011.

After we implement the proposed TCH plan which consists now of 12 TCHs instead of 16 TCHs it is essential to compare the peak carried traffic during October, 2011 with the offered from the 12 TCH plan from the Erlang B table. From Figure 6.6, it is noted the nearly all the cells are capable of handling the peak carried traffic during October, 2011, except the cells JMIC03B, JMIC06C and JENI01B. JMIC03B is congested cell so we added another site which is JMIC06, also JMIC06 was congested since it was operating using one TRU due to hardware issues. The cell JENI01B, JENI15A suffer from a little bit congestion, but it is not critical.

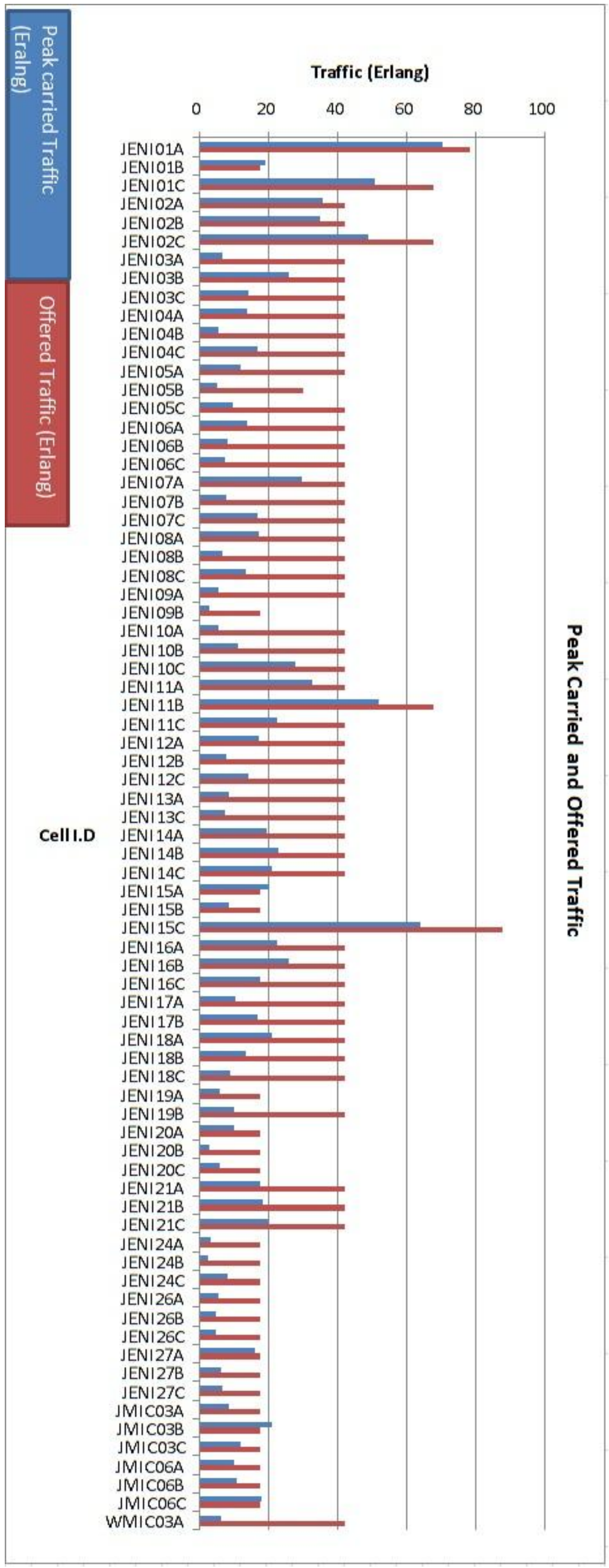

Figure 6.6: Peak carried traffic during October, 2011 vs. offered traffic from Erlang B table considering the new TCH plan (12 TCHs)

6.2.4 TCH assignment success rate

Figure 6.7 shows the performance of TCH assignment success rate for Jenien city cell set in October, 2011. The average of the TCH assignment success rate is now equals 99.79%, while it was 99.76% before the work in Jenien city started in November, 2010. So there is a little bit of enhancement in the TCH assignment success rate. Which is a direct result of the reduced interference level on the GSM network in Jenien city.

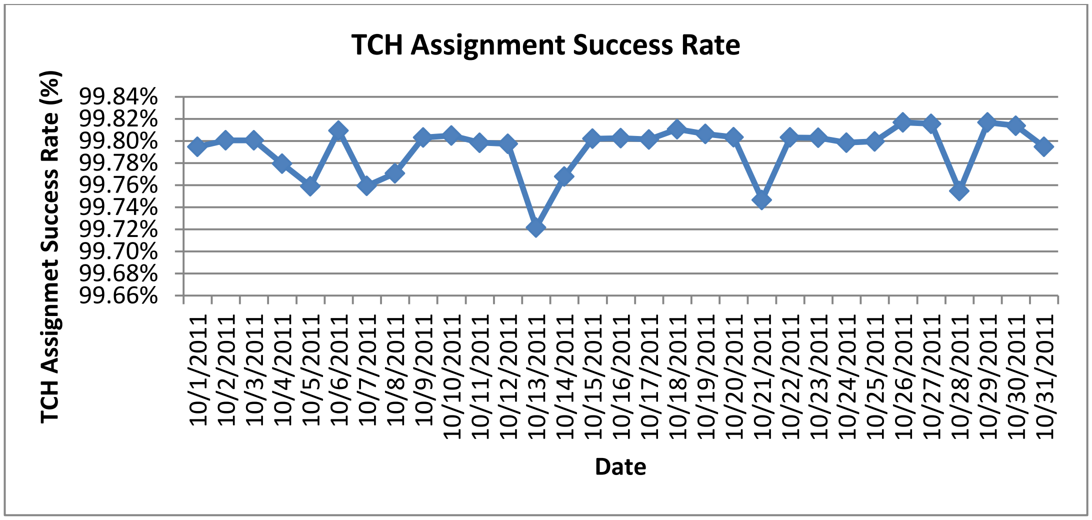

Figure 6.7: TCH assignment success rate for Jenien city cell set in October, 2011.

6.2.5 Handover success rate

The last KPI we are going to discuss is the handover success rate. Figure 6.8 shows the performance of this KPI during the month of October, 2011. It is noted that the average of the handover success rate now is now 96.12% while it was before 95.75%. Thus, there is some improvement in the handover success rate after the work is finished in Jenien city. The better handover success rate is reflected in reduced TCH drop rate, it also indication of a well designed neighbor relation plan.

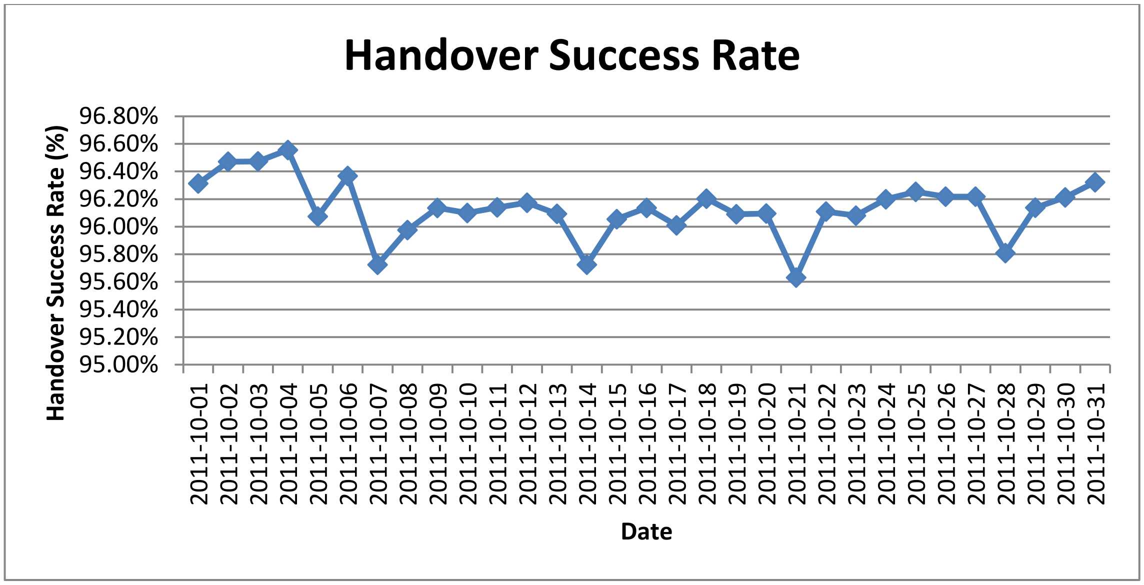

Figure 6.8: Handover success rate for Jenien city cell set in October, 2011.

6.3 Worst Performing Cells

1. TCH drop rate worst performing cells

Figure 6.9 shows the top 10 worst performing cells in terms of TCH drop rate in October, 2011. It is noted that there is some new cells are now with high TCH drop rate such as JENI26A, JENI24B and JENI27A. These cells are new integrated cells that need more work in order to reduce the TCH drop. The work on these cells will be mostly physical changes in order to enhance the performance of these cells. These physical changes are beyond the scope of this research. Nevertheless, this will be discussed in chapter 7 in the section dedicated for future work.

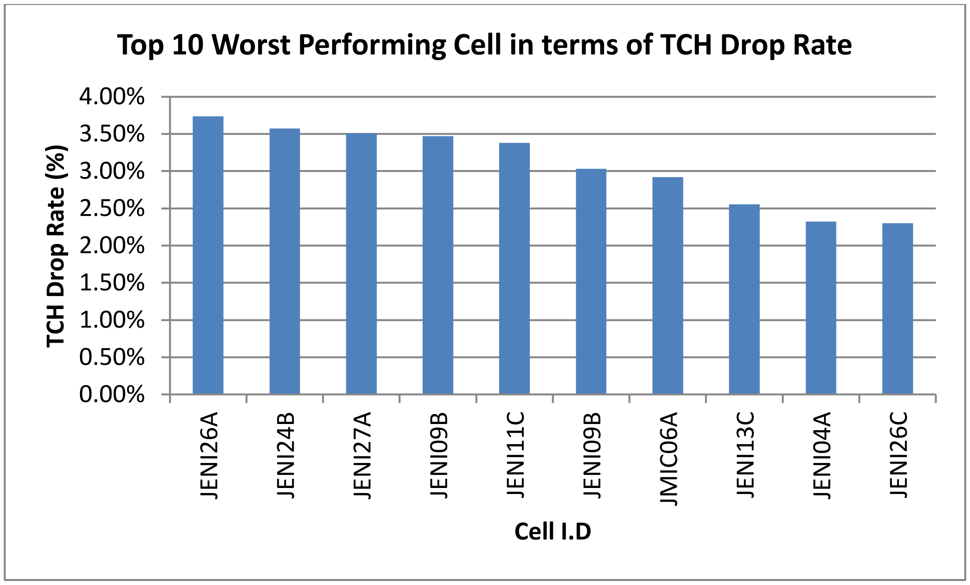

Figure 6.9: Top 10 worst performing cells in terms of TCH drop rate in Jenien city during October, 2011.

For the worst performing cell which is JENI26A with TCH drop rate of 3.73%, the reasons for that high TCH drop rate are illustrated by Figure 6.9.

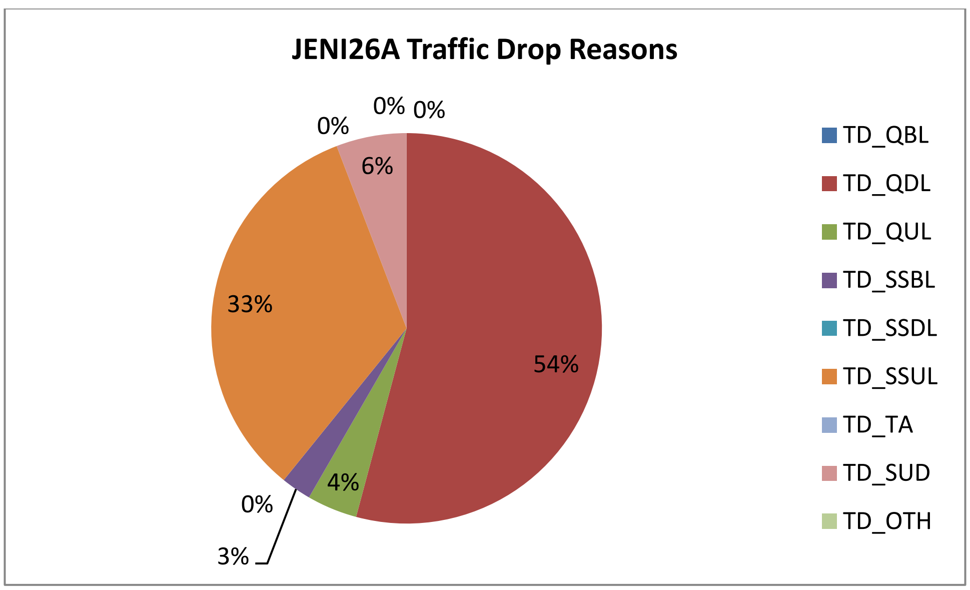

Figure 6.10: JENI26A TCH drop rate reasons.

Figure 6.10 shows that 54% of the TCH drop rate on the cell JENI26A is due to quality in DL. But there is another reason for the high TCH drop rate which is TD_SSUL. This cell serves far areas so the MS could not transmit more power to keep the connection between the MS and BTS. This issue can be solved by limiting the cell from these far areas to reduce the percentages of TD_SSUL and TD_QDL.

2. **SDCCH drop rate worst performing cells**

From Figure 6.11 the reader can find the SDCCH top 10 worst performing cells in Jenien city during October, 2011.

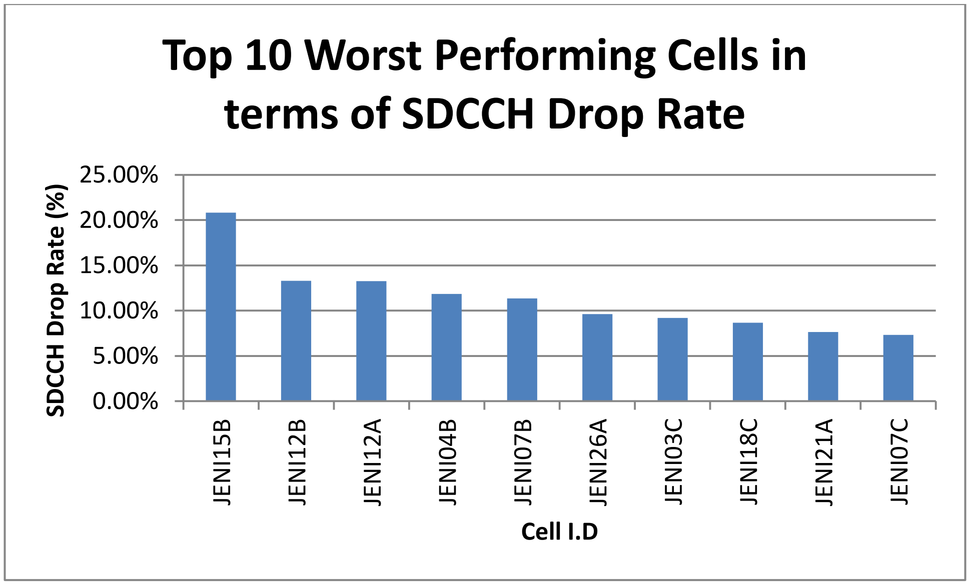

Figure 6.11: Top 10 worst performing cells in terms of SDCCH drop rate in Jenien city during October, 2011.

From Figure 6.11 it is noted that the cell JENI15B suffers from more than 20% of SDCCH drop rate. The main reason for that high SDCCH drop is others reason as shown in Figure 6.12.

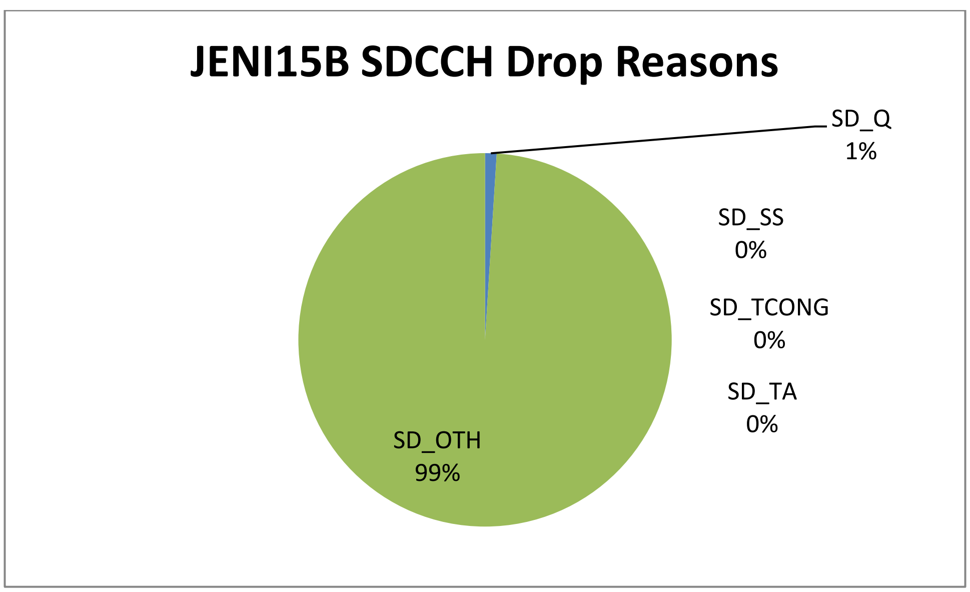

Figure 6.12: JENI15B SDCCH drop rate reasons.

The others reason for SDCCH drop rate is a real problem for the cell JENI15B and for the overall SDCCH drop rate for Jawwal GSM network. As mentioned earlier, Jawwal works to fix this issue with a major concern.

3. TCH congestion and subscriber perceived TCH congestion

From Figure 3.5 we noted that some of the cells that serve the city center in Jenien are congested. This leads us to build new micro sites to serve the same area. The first micro site named JMIC03 is now congested but another micro site named JMIC06 is recently activated.

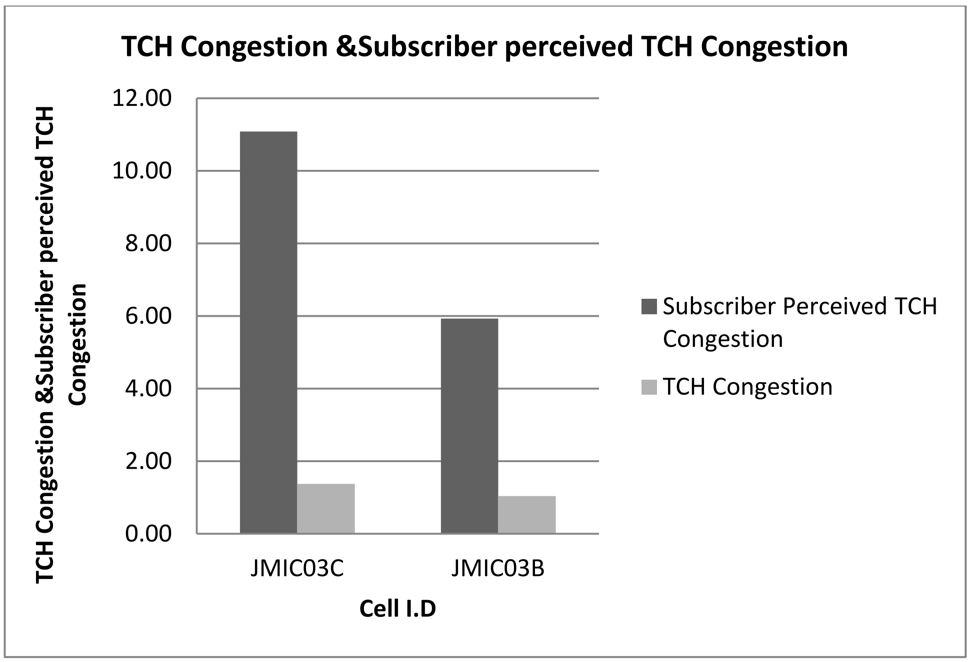

Figure 6.13: Worst performing cells in terms of TCH congestion and subscriber perceived TCH congestion in Jenien city during October, 2011.

The newly activated micro site JMIC06 will reduce the existed congestion on the site JMIC03.

4. TCH assignment success rate

Now we will list the worst performing cells in terms of TCH assignment success rate in Jenien city. Figure 6.14 shows these cells.

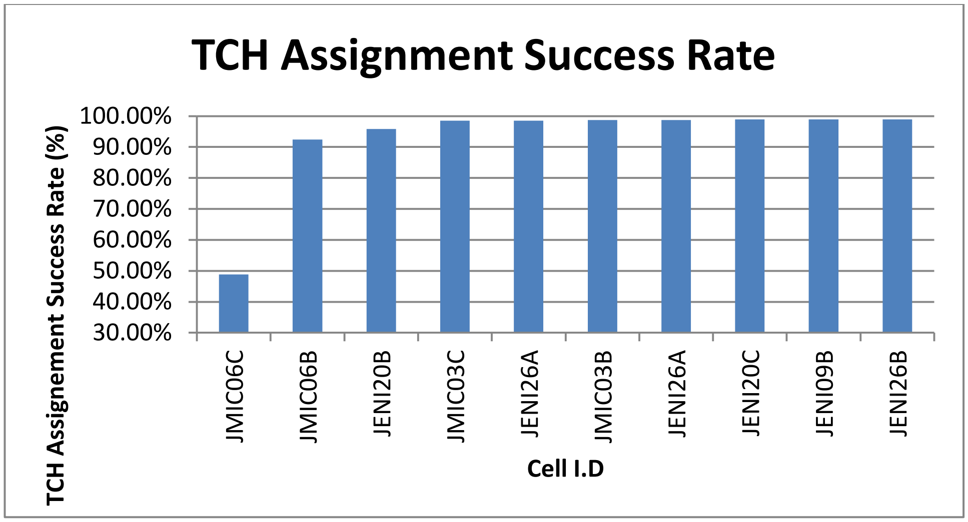

Figure 6.14: Worst performing cells in terms of TCH assignment success rate in Jenien city during October, 2011.

We can note that the worst cell in terms of TCH assignment success rate is JMIC06C with only about 50%. JMIC06C was suffering from hardware issues that makes only one TRU working and that results in poor TCH assignment success rate.

5. Handover Success Rate

For the handover success rate, the worst performing cells in Jenien city are given in Figure 6.15.

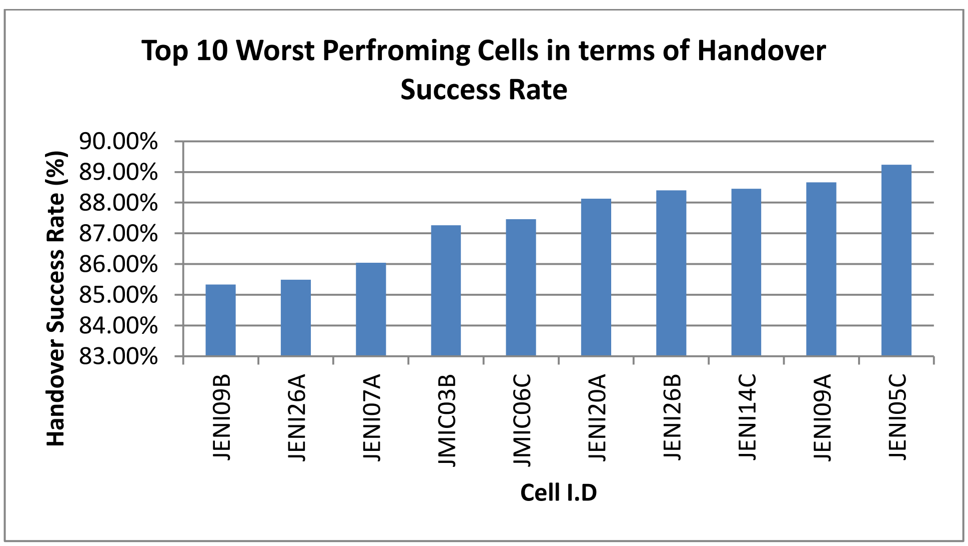

Figure 6.15: Worst performing cells in terms of handover success rate in Jenien city during October, 2011.

Note that the cells with poor handover performance such as JENI09B and JENI26A suffer also from high TCH drop rate. This indicates that these cells are suffering from poor quality so MS fail to connect to these cells.

6.4 Comparative Study Using Drive Test Analysis

This is the second stage in the comparative study, in which the drive test analysis is introduced. Here, we will start by taking a look at overall Jenien city from the percentage distribution of each coverage class, RXLEVSUB and RXQUALSUB distribution figures and design validation tables. Here, we will keep our eyes on the percentage of level 1 and percentage of level 4.

6.4.1 Drive test analysis for Jenien city

It should be remembered at this stage that the main goal of this research is to reduce the percentage of the samples in level 4 and to increase the percentage of the samples in level 1 or level 2. Let us start with Table 6.1 that shows the percentages of each level after enhancing is Jawwal GSM network in October, 2011. This should be compared with the corresponding tables of chapter 4 obtained in August, 2010.

RXLEVSUB/ RXQUALSUB	RXQUALSUB≤ 2	2<RXQUALSUB≤ 4	4<RXQUALSUB≤ 6	RXQUALSUB> 6	Any RXQUALSUB	Coverage Class	%
RXLEVSUB≥-70	76.77	4.82	4.52	3.18	89.29	Leve1 1	76.77
-70 ≥ RXLEVSUB ≥ -85	5.71	1.17	1.69	1.81	10.38	Leve1 2	11.70
-85≥ RXLEVSUB ≥-100	0.07	0.05	0.05	0.17	0.34	Leve1 3	6.38
RXLEVSUB ≤ -100	0.00	0.00	0.00	0.00	0.00	Leve1 4	5.16
Any RXLEVSUB	82.55	6.04	6.26	5.16	100.00	Total	100.00

Table 6.1: Percentage distribution of coverage classes of Jawwal GSM network in Jenien City in October, 2011.

From Table 6.1, it is noted that:

1. The percentage of level 1 is now about 77% compared to only 65% before the work started. The increase on this level is about 10%.
2. Another important achievement is the percentage of level 4 is now reduced to be about 5%. It was 8% before conducting this research.
3. Level 2 is reduced from 15% to 11% now.
4. Level 3 is reduced from 11% to 6%.

Figure 6.16 shows the RXLEVSUB distributions in Jenien city during October, 2011.

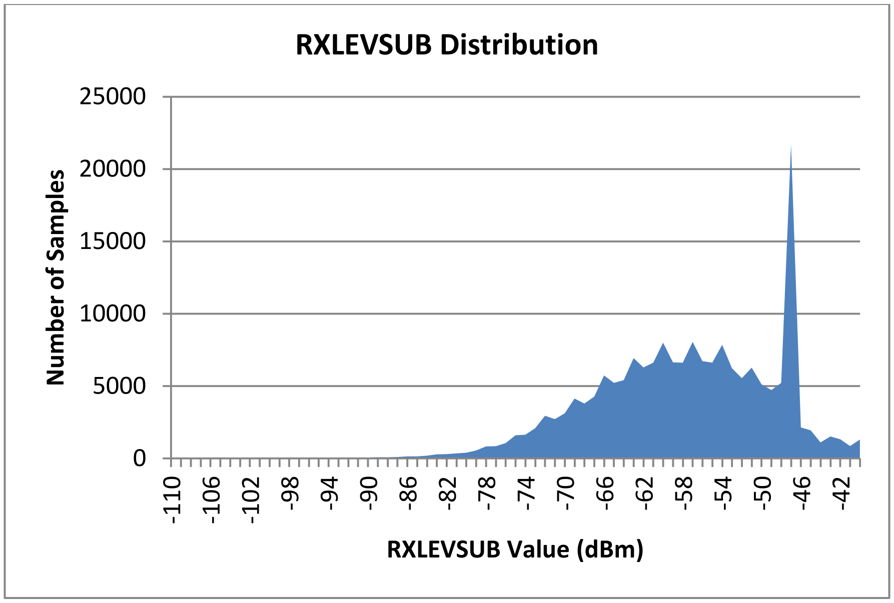

Figure 6.16: RXLEVSUB distribution of Jenien city in October, 2011.

From Figure 6.16, it is noted that approximately all samples lie between the values of -42 dBm and -85 dBm. This comes from the fact of activating planned sites in Jenien city, such as JENI24, JENI26, JEN27, JMIC03 and JMIC06. The average of RXLEVSUB samples that are collected in October, 2011 equals -57.78 dBm and the standard deviation is 9.06.
Now let us move to the RXQUALSUB distributions in Jenien city after the enhancement which is presented in Figure 6.17.

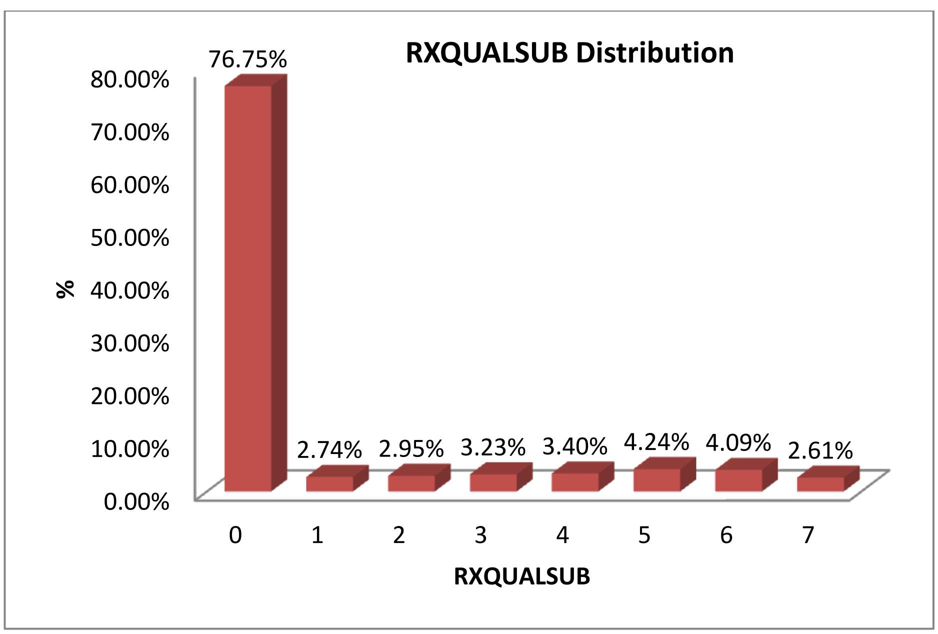

Figure 6.17: RXQUALSUB distribution of Jenien city in October, 2011.

From Figure 6.17, it is noted that about 77% of the samples now having RXQUALSUB of 0 compared with only 69% of the samples with RXQUALSUB of 0. As mentioned earlier, the

poor RXQUALSUB are the samples with RXQUALSUB of 6 and 7. About 6.7% of the samples are considered poor RXQUALSUB now as shown in Figure 6.16. The poor RXQUALSUB was 9.9% before the work started in Jenien city.
Table 6.2 shows the percentage of the reasons that result in poor performance after the enhancement of Jawwal network in Jenien city.

Cause	**Percent**
Interference	34.47%
Poor Level	0.20%
Poor Quality and Poor Level	0.65%
No Dominance	46.55%
Interference and No Dominance	17.57%
Poor Level and No Dominance	0.12%
Poor Quality, Poor Level and No Dominance	0.44%

Table 6.2: Poor design reasons with their percentage for Jenien city in October, 2011.

It is noted that interference is now in the second place causing poor performance for Jawwal GSM network in Jenien city with 34%. Note that interference was playing the major role before the work started in Jenien city with nearly 49%. This means that interference still exist and can participate in affecting Jawwal GSM network but it does not play the major role now. The no dominance issue is now ranked as number one. The no dominance issue will be discussed in the future work section of chapter 7.

6.4.2 Mrah area

In this subsection, the percentage of each coverage class obtained in October, 2011 for Mrah area is compared with that obtained before this research.

RXLEVSUB/ RXQUALSUB	RXQUALSUB≤ 2	2<RXQUALSUB≤ 4	4<RXQUALSUB≤ 6	RXQUALSUB> 6	Any RXQUALSUB	Coverage Class	%
RXLEVSUB≥-70	84.28	3.86	3.31	1.65	93.10	Level 1	84.28
-70 ≥ RXLEVSUB ≥ -85	5.33	0.55	0.55	0.46	6.89	Level 2	9.74
-85≥ RXLEVSUB ≥-100	0.00	0.00	0.00	0.00	0.00	Level 3	3.86
RXLEVSUB ≤ -100	0.00	0.00	0.00	0.00	0.00	Level 4	2.11
Any RXLEVSUB	89.61	4.41	3.86	2.11	100.00	Total	100.00

Table 6.3: Percentage distribution of coverage classes of Jawwal GSM network in Mrah area in October, 2011.

When comparing Tables 6.3 and Table 4.6, there is a significant improvement in Mrah area:

1. The major improvement in this area is the percentage of level 1, which is increased from 71% to 84%.
2. Level 4 is reduced from about 5% to 2%.
3. Lever 2 is reduced from about 17% to 9%.
4. Level 3 is also reduced from 6.85% to 3.86%.

The RXLEVSUB distribution is shown in Figure 6.18. It is noted that the samples have values of RXLEVSUB from -42 dBm to -85 dBm. There is no samples with poor coverage at this area as two additional sites are activated which are JENI20 and JENI24. The average of the collected samples for RXLEVSUB is -59.27 dBm and the standard deviation is 8.11.

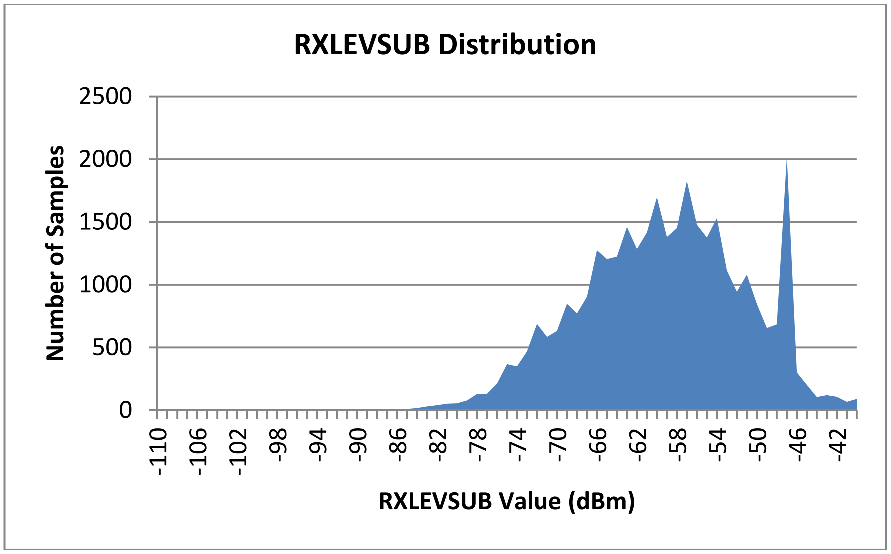

Figure 6.18: RXLEVSUB distribution in Mrah area in October, 2011.

RXQUALSUB distribution is shown in the Figure 6.19.

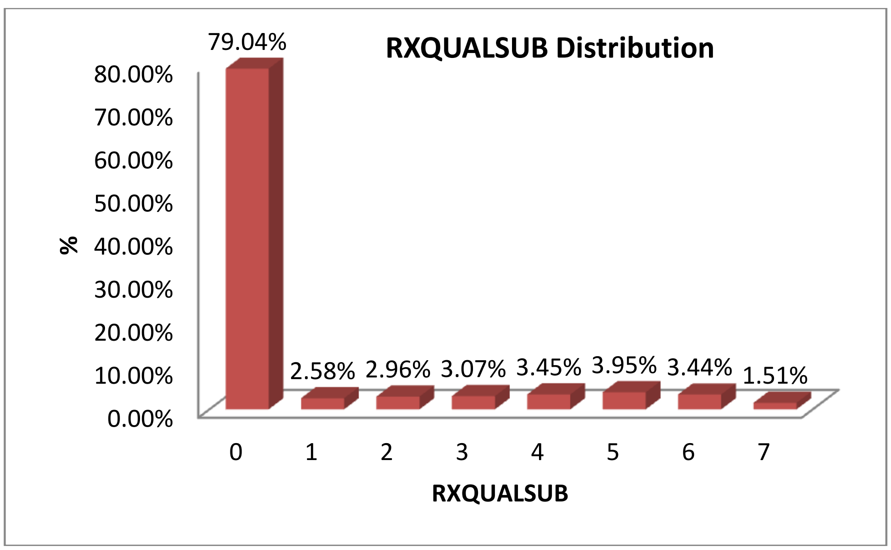

Figure 6.19: RXQUALSUB distribution in Mrah area in October, 2011.

The RXQUALSUB of 0 is now with 79% in October, 2011 compared to about 75% before carrying out this research. Also, the poor RXQUALSUB samples are now 5% compared to 7% before.

The design validation is another tool for detecting the main reasons that results in poor performance, which is shown in the Table 6.4 for Mrah area.

Cause	Percent
Interference	32.90%
Poor Level	0.04%
Poor Quality and Poor Level	0.05%
No Dominance	51.04%
Interference and No Dominance	15.96%
Poor Level and No Dominance	0.02%
Poor Quality, Poor Level and No Dominance	0.00%

Table 6.4: Poor design reasons with their percentage for Mrah area in October, 2011.

Interference is now 33% responsible for causing poor performance of Jawwal GSM network in Mrah area. No dominance is on the top of those reasons with more than 50%. The interference was ranked as number one reason that makes poor performance of Jawwal network in Mrah area before the enhancement work with a percentage of 64%.

Figure 6.20, Figure 6.21, Figure 6.22, Figure 6.23, Figure 6.24 and Figure 6.25 present, respectively, the RXLEVSUB, RXQUALSUB, serving BCCH, RXQUALSUB with dropped calls, serving CI and serving BSIC.

Figure 6.20: RXLEVSUB of Mrah area in October, 2011.

Figure 6.21: RXQUALSUB of Mrah area in October, 2011.

Figure 6.22: Serving BCCH for Mrah area in October, 2011.

Figure 6.23: RXQUALSUB with dropped calls for Mrah area in October, 2011.

Figure 6.24: Serving CI for Mrah area in October, 2011.

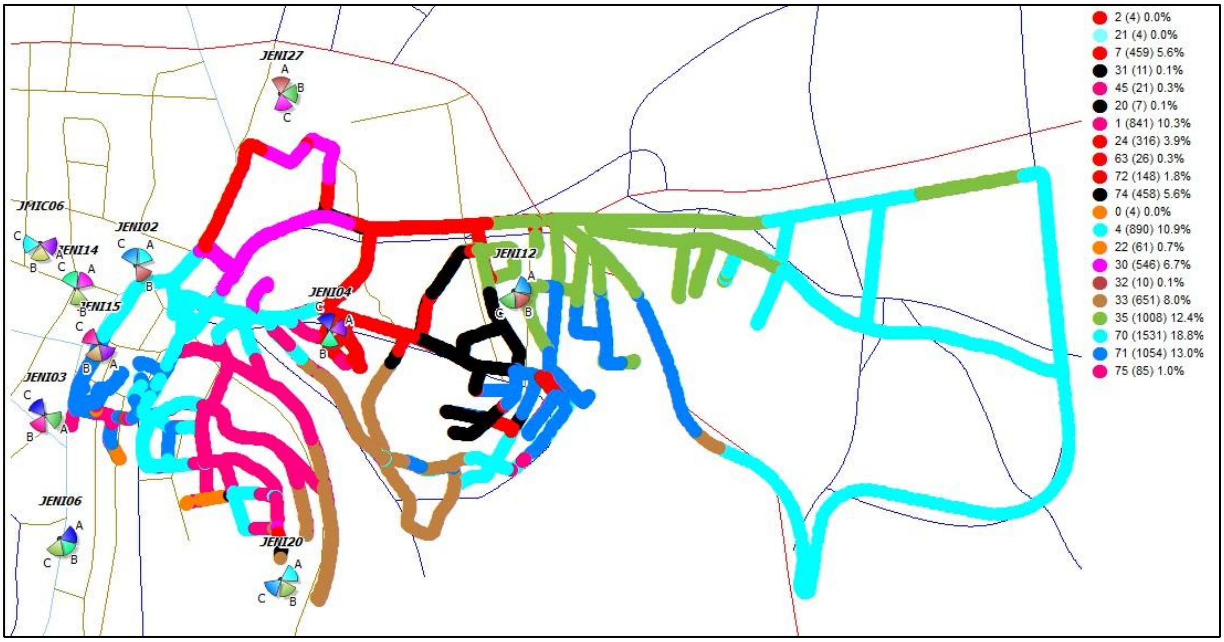

Figure 6.25: Serving BSIC for Mrah area in October, 2011.

When you compare the RXLEVSUB and RXQUALSUB for Mrah area before and after the enhancement, it is noted that there is improvement in both RXLEVSUB and RXQUALSUB at some points on the maps. Also, if we do compare Figures 4.7 and 6.23, it is noted that the number of dropped calls in Figure 4.7 was 4 dropped calls due to poor RXQUALSUB, while it is only 1 drop call due to poor RXQUALSUB in Figure 6.23.This is another result for the reduced interference level after the work in Jenien city.

6.4.3 Ballad area

Here we present the results for the next area in Jenien city which is Ballad area. Let us first start with the table that shows the percentage of each coverage class after the work is finished in Jenien city.

RXLEVSUB/ RXQUALSUB	RXQUALSUB≤ 2	2<RXQUALSUB≤ 4	4<RXQUALSUB≤ 6	RXQUALSUB> 6	Any RXQUALSUB	Coverage Class	%
RXLEVSUB≥-70	84.35	5.80	4.64	3.09	97.88	Level 1	84.35
-70 ≥ RXLEVSUB ≥ -85	1.55	0.29	0.19	0.10	2.13	Level 2	7.64
-85≥ RXLEVSUB ≥-100	0.00	0.00	0.00	0.00	0.00	Level 3	4.83
RXLEVSUB ≤ -100	0.00	0.00	0.00	0.00	0.00	Level 4	3.19
Any RXLEVSUB	85.90	6.09	4.83	3.19	100.00	Total	100.00

Table 6.5: Percentage distribution of coverage classes of Jawwal GSM network in Ballad area in October, 2011.

When comparing the Tables 4.8 and 6.5 for Ballad area, the following points are obtained:

1. The increase in level 1 is from 74% to 84% which is 10% increase in the best level.
2. Level 4 is decreased from 5.5% to about 3%.
3. Level 2 is reduced from 10.8% to 7.64%.
4. Level 3 is also reduced from 9.5% to 4.83%

Let us now check the RXLEVSUB distribution for Ballad area, which is shown in Figure 6.25.

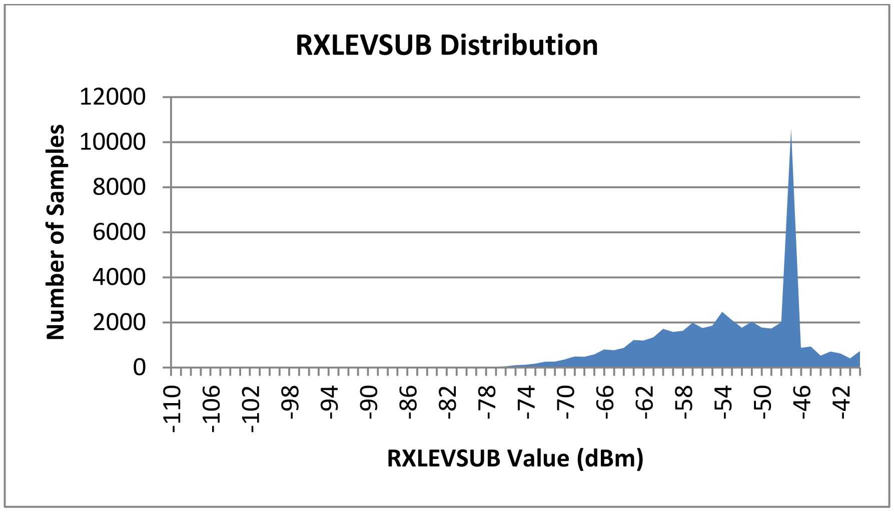

Figure 6.26: RXLEVSUB distribution in Ballad area in October, 2011.

The coverage in Ballad area is now better after activating JMIC03 and JMIC06. This is obvious from Figure 6.26 and Figure 4.12. The average for RXLEVSUB is now -53.48 dBm and the standard deviation is 7.44.
The RXQUALSUB is shown in Figure 6.27. In which the RXQUALSUB with value of 0 is now about 78% compared to 68.5% before (Figure 4.13). Also the poor RXQUALSUB is now 5.8% compared to 8% before the work started (Figure 4.13).

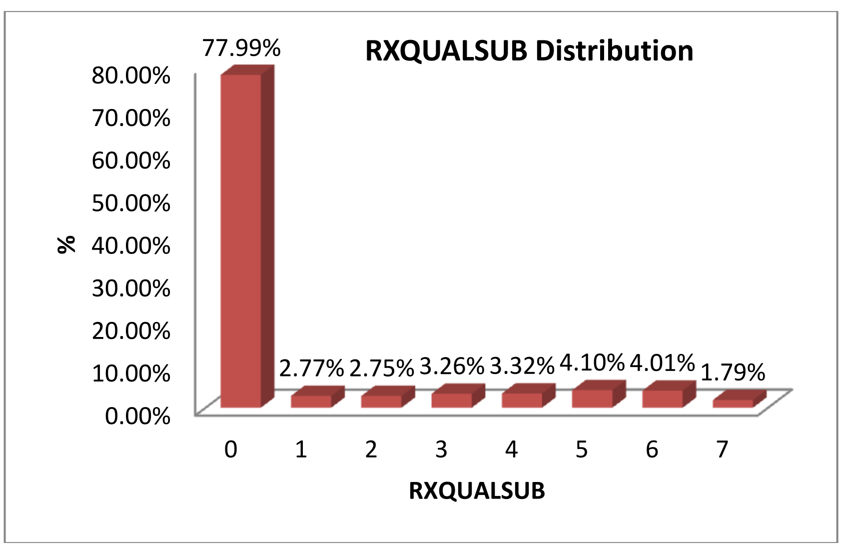

Figure 6.27: RXQUALSUB distribution in Ballad area in October, 2011.

The design validation is shown in Table 6.6 in which the percentage of interference is reduced dramatically from 71% to 38% from Table 4.9.

Cause	Percent
Interference	38.05%
Poor Level	0.00%
Poor Quality and Poor Level	0.00%
No Dominance	48.60%
Interference and No Dominance	13.35%
Poor Level and No Dominance	0.00%
Poor Quality, Poor Level and No Dominance	0.00%

Table 6.6: Poor design reasons with their percentage for Ballad area in October, 2011.

6.4.4 Hadaf area

Starting with the coverage classes for Hadaf area in October 2011, Table 6.7. Comparing the percentages of each level for Hadaf area before (Table 4.10) and after the enhancement in Jenien city yields that:

1. Level 1 is increased from 57% to 76%.
2. The worst level 4 it is reduced from 11.7% to only 4.93%.
3. Level 2 is also reduced from 14.65% to 10.45%.
4. Level 3 is also reduced from 15.88% to 8.13%.

RXLEVSUB/ RXQUALSUB	RXQUALSUB≤ 2	2<RXQUALSUB≤ 4	4<RXQUALSUB≤ 6	RXQUALSUB> 6	Any RXQUALSUB	Coverage Class	%
RXLEVSUB≥-70	76.49	4.79	5.66	3.48	90.42	Level 1	76.49
-70 ≥ RXLEVSUB ≥ -85	4.06	1.60	2.47	1.45	9.58	Level 2	10.45
-85≥ RXLEVSUB ≥-100	0.00	0.00	0.00	0.00	0.00	Level 3	8.13
RXLEVSUB ≤ -100	0.00	0.00	0.00	0.00	0.00	Level 4	4.93
Any RXLEVSUB	80.55	6.39	8.13	4.93	100.00	Total	100.00

Table 6.7: Percentage distribution of coverage classes of Jawwal GSM network in Hadaf area in October, 2011

To enforce the previous numbers, take a look at the RXLEVSUB and RXQUALSUB distribution figures. Starting with the RXLEVSUB.

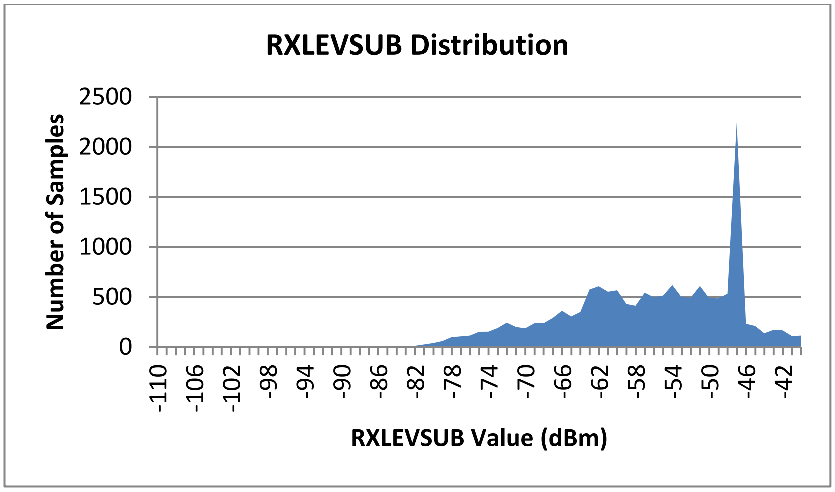

Figure 6.28: RXLEVSUB distribution in Hadaf area in October, 2011.

From Figure 6.28 it is noted that this area is covered well now specially after activating the site JENI26. There is no poor covered spot at this area since the samples have RXLEVSUB between -42 dBm to -82 dBm. When comparing Figures 6.28 and 4.14, it is noted that before the enhancement work this area was suffering from poor coverage given by samples with RXLEVSUB < -86 dBm. After performing this research, all the samples are within the -42 to -82 dBm. The average of RXLEVSUB samples is now -56.60 dBm and the standard deviation equals 9.16.
For RXQUALSUB distribution in Figure 6.29, it is noted that there is a large increase at the RXQUALSUB of 0 value at this area from about 63.5% to 82.8% from Figure 4.15 and Figure 6.27. That is also reflected on the poor RXQUALSUB which was about 12% and now it is reduced to only 5%.

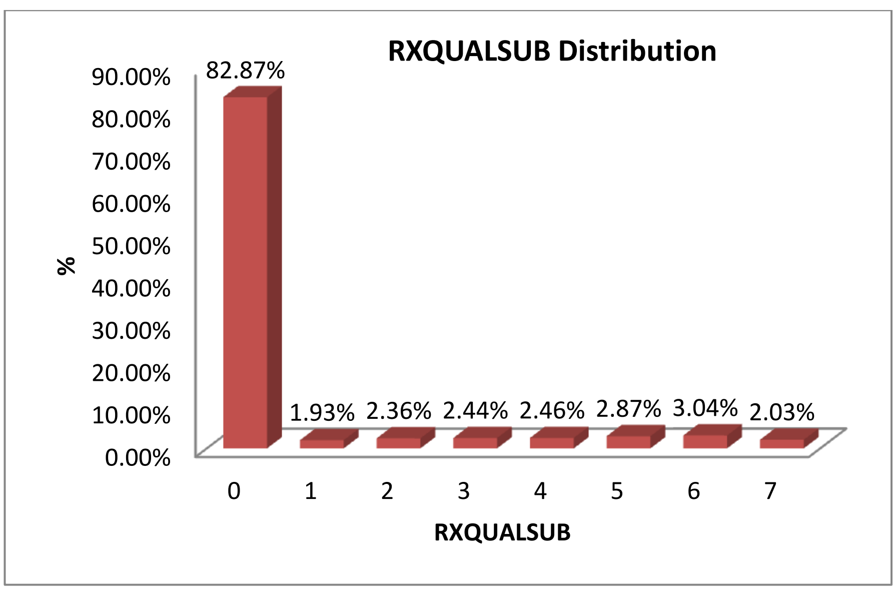

Figure 6.29: RXQUALSUB distribution in Hadaf area in October, 2011.

For the design validation at Hadaf area, Table 6.8, shows the percentage of each reason behind the poor performance of Jawwal GSM network in Hadaf area as follows:

Cause	Percent
Interference	35.60%
Poor Level	0.03%
Poor Quality and Poor Level	0.03%
No Dominance	44.85%
Interference and No Dominance	19.49%
Poor Level and No Dominance	0.00%
Poor Quality, Poor Level and No Dominance	0.00%

Table 6.8: Poor design reasons with their percentage for Hadaf area in October, 2011.

Table 6.8 presents that interference is now with 35% responsible of the poor performance of Jawwal GSM network in Hadaf area. If you take a look back before the work started on Jenien city which is given by Table 4.11, the percentage for interference was 60%.

6.4.5 Industrial area

Comparing Table 6.9 which shows the percentage of each coverage class after the work in Jenien city for Industrial with Table 4.12 gives us:

1. Level 1 is the biggest winner after the work in Jenien city since it is increased from 70% to 81%.
2. Level 4 is the other winner here as it is reduced from 7% to 5%.
3. Level 2 is reduced no to 8.6% compared to 11.6% before the work started.
4. Level 3 is reduced from 10.7% to 4.8%

RXLEVSUB/ RXQUALSUB	RXQUALSUB≤ 2	2<RXQUALSUB≤ 4	4<RXQUALSUB≤ 6	RXQUALSUB> 6	Any RXQUALSUB	Coverage Class	%
RXLEVSUB≥-70	81.69	7.94	4.49	4.32	98.44	Level 1	81.49
-70 ≥ RXLEVSUB ≥ -85	0.52	0.17	0.35	0.52	1.56	Level 2	8.63
-85≥ RXLEVSUB ≥-100	0.00	0.00	0.00	0.00	0.00	Level 3	4.84
RXLEVSUB ≤ -100	0.00	0.00	0.00	0.00	0.00	Level 4	4.84
Any RXLEVSUB	82.21	8.11	4.84	4.84	100	Total	100

Table 6.9: Percentage distribution of coverage classes of Jawwal GSM network in Industrial area in October, 2011

RXLEVSUB distribution is shown in the Figure 6.30 which demonstrates that Industrial area is well covered area. This is obvious from Figure 6.30 since all the samples are within -42 dBm to -82 dBm. JENI27 is recently activated site inside Industrial area and this site enforced the coverage even better. The average of the RXLEVSUB now equals -57.53 dBm while the standard deviation equals 7.57. Figure 4.16 shows that there was samples with poor coverage, however the area is well covered now.

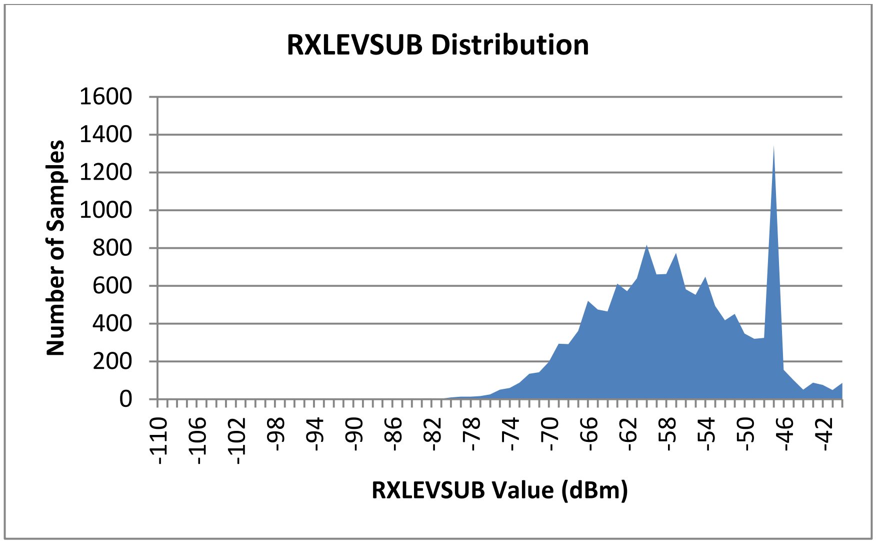

Figure 6.30: RXLEVSUB distribution in Industrial area in October, 2011.

RXQUALSUB distribution is shown in figure 6.31 in which it is noted that 75.3% of the samples are now having 0 RXQUALSUB compared to 69.5% before the work is started, Figure 4.17. Poor RXQUALSUB is now 7% compared to 8%.

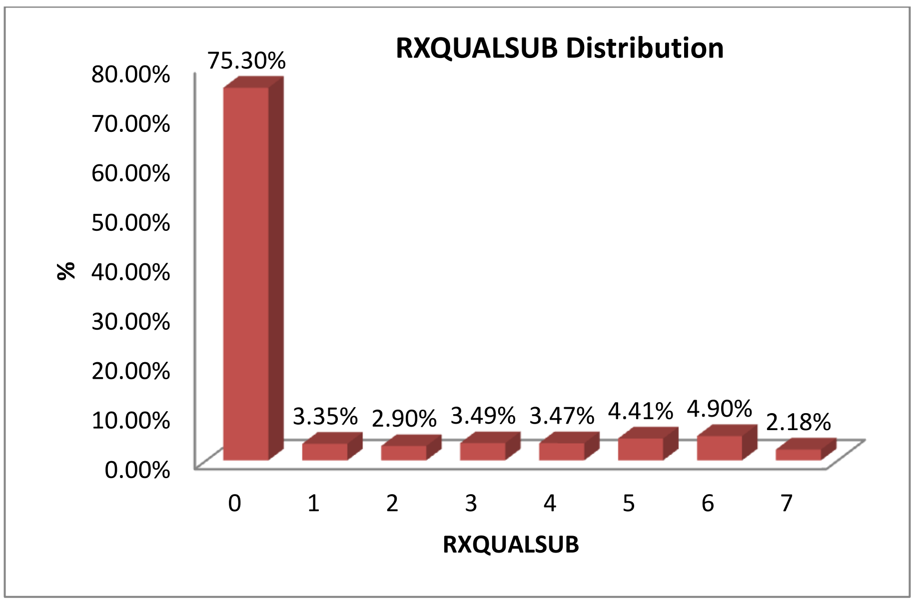

Figure 6.31: RXQUALSUB distribution in Industrial area in October, 2011.

The design validation is shown in Table 6.10. From this table it is noted that the interference is now back from being number one reason with 60% to only 29% (Table 4.13).

Cause	Percent
Interference	28.74%
Poor Level	0.00%
Poor Quality and Poor Level	0.00%
No Dominance	53.45%
Interference and No Dominance	17.81%
Poor Level and No Dominance	0.00%
Poor Quality, Poor Level and No Dominance	0.00%

Table 6.10: Poor design reasons with their percentage for Industrial area in October, 2011.

6.4.6 Swettat Area

The percentage of coverage classes for Swettat area are shown in Table 6.11. If you compare this table with Table 4.14, you will get the following:

1. Good results for level 1 which increased from 55% to 61%.
2. Also the good performance of this area is reflected on the level 4 which is reduced from 9% to 7%.
3. There is no significant change in level 2.
4. Level 3 is reduced from 12.8% to 7.4%.

RXLEVSUB/ RXQUALSUB	RXQUALSUB≤ 2	2<RXQUALSUB≤ 4	4<RXQUALSUB≤ 6	RXQUALSUB> 6	Any RXQUALSUB	Coverage Class	%
RXLEVSUB≥-70	61.23	3.95	3.38	2.44	70.90	Level 1	61.23
-70 ≥ RXLEVSUB ≥ -85	15.48	3.36	4.54	4.54	27.92	Level 2	22.79
-85≥ RXLEVSUB ≥-100	0.25	0.17	0.25	0.50	1.17	Level 3	8.49
RXLEVSUB ≤ -100	0.00	0.00	0.00	0.00	0.00	Level 4	7.48
Any RXLEVSUB	76.96	7.48	8.07	7.48	100	Total	100

Table 6.11: Percentage distribution of coverage classes of Jawwal GSM network in Swettat area in October, 2011.

Next is Figure 6.32 which shows the RXLEVSUB distribution in Swettat area. This figure shows a well covered area specially after activation of JENI20. The average RXLEVSUB for this area is -63.46 dBm and the standard deviation is 9.95. There is no significant change at this area in terms of RXLEVSUB as noted from Figure 4.18 and Figure 6.32.

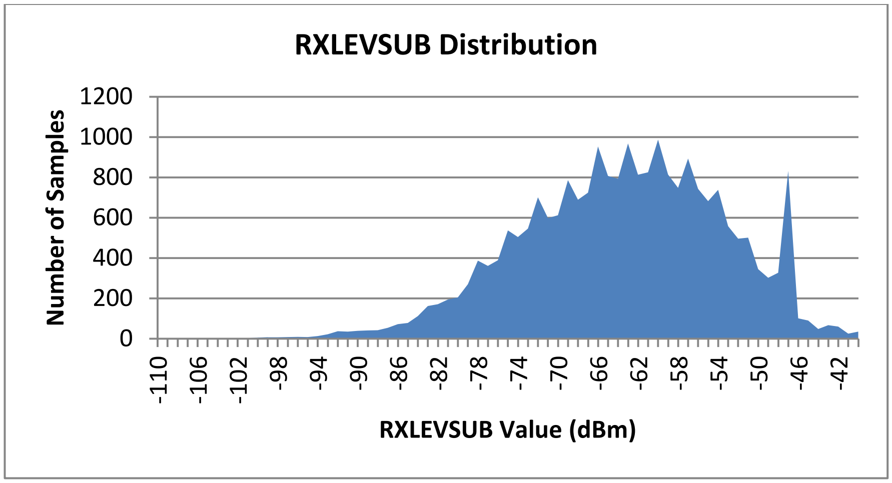

Figure 6.32: RXLEVSUB distribution in Swettat area in October, 2011.

RXQUALSUB distribution is shown in Figure 6.33, which shows that RXQUALSUB with 0 value are now about 72.6% of the samples compared to 64.9% before as from Figure 4.19. Also the poor RXQUALSUB are now 8.5% compared to about 13% before.

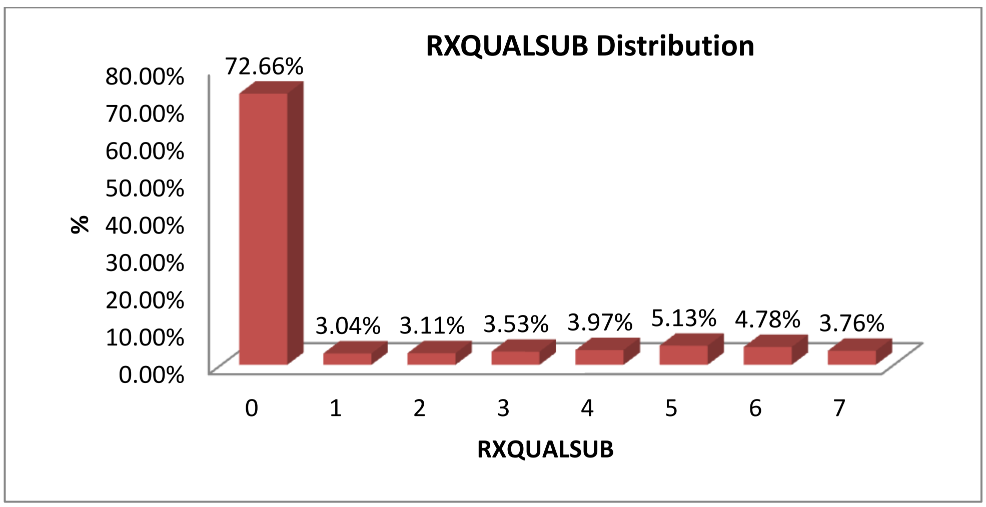

Figure 6.33: RXQUALSUB distribution in Swettat area in October, 2011.

The design validation is shown in Table 6.12 which shows that interference reason is now reduced from 62% (Table 4.15) to only 33% after the work.

Cause	**Percent**
Interference	33.58%
Poor Level	0.76%
Poor Quality and Poor Level	2.53%
No Dominance	40.49%
Interference and No Dominance	20.19%
Poor Level and No Dominance	0.53%
Poor Quality, Poor Level and No Dominance	1.93%

Table 6.12: Poor design reasons with their percentage for Swettat area in October, 2011.

6.4.7 Kharoubeh area

Table 6.13 that shows the coverage classes at each level in Kharoubeh area after the work in Jenien city. By taking a look back to Table 4.16, then do comparisons between the two tables for this area before and after, it is noted that:

1. Level 1 increased from 57% to 70%.
2. Level 4 reduced from 15% to 9%.
3. Level 2 is reduced from 12.8% to 10.9%.
4. Level 3 is also reduced from 14.9% to 9.1%.

RXLEVSUB/ RXQUALSUB	RXQUALSUB≤ 2	2<RXQUALSUB≤ 4	4<RXQUALSUB≤ 6	RXQUALSUB> 6	Any RXQUALSUB	Coverage Class	%
RXLEVSUB≥-70	70.50	8.22	7.31	6.79	92.82	Level 1	70.50
-70 ≥ RXLEVSUB ≥ -85	1.44	1.31	1.83	2.61	7.19	Level 2	10.97
-85≥ RXLEVSUB ≥-100	0.00	0.00	0.00	0.00	0.00	Level 3	9.14
RXLEVSUB ≤ -100	0.00	0.00	0.00	0.00	0.00	Level 4	9.40
Any RXLEVSUB	71.94	9.53	9.14	9.40	100	Total	100

Table 6.13: Percentage distribution of coverage classes of Jawwal GSM network in Kharoubeh area in October 2011

RXLEVSUB distribution is shown in Figure 6.34. After the work is finished, also it comes even better in terms of RXLEVSUB. The average of the collected samples of RXLEVSUB is -60.42 dBm while the standard deviation is now 8.15, as compared to Figure 4.20.

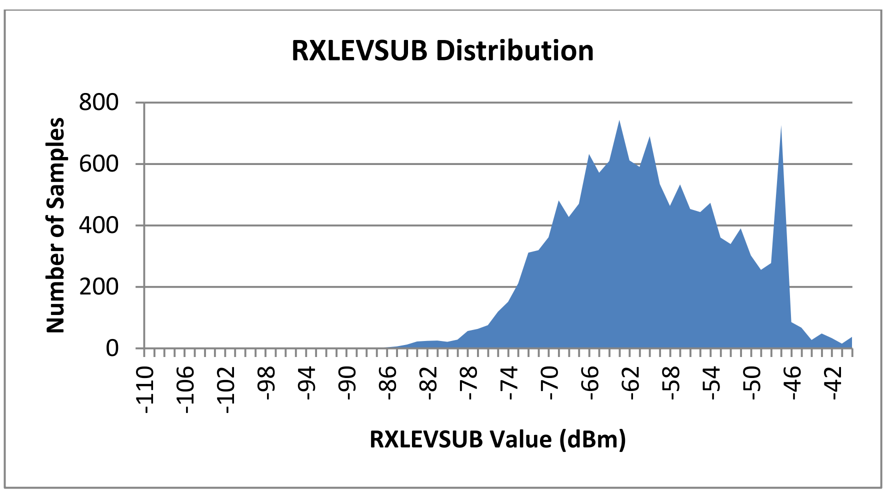

Figure 6.34: RXLEVSUB distribution in Kharoubeh area in October, 2011.

RXQUALSUB distribution at this area shows that the samples having RXQUALSUB value of 0 is now 60.2% compared to 53.8% before (Figure 4.21).
The poor RXQUALSUB is now lowered to 14% compared to 18% before as reported from Figure 6.35.

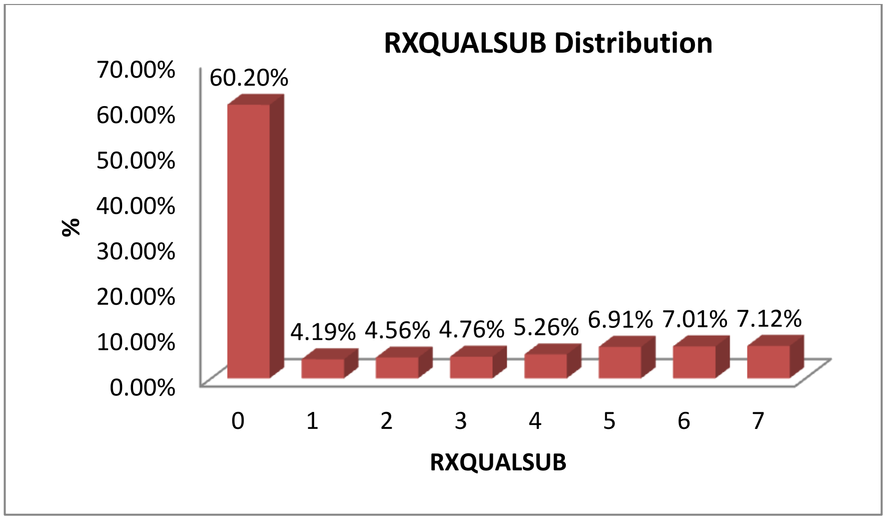

Figure 6.35: RXQUALSUB distribution in Kharoubeh area in October, 2011.

It is the time for design validation now, which is shown in the Table 6.14.

Cause	Percent
Interference	40.99%
Poor Level	0.04%
Poor Quality and Poor Level	0.02%
No Dominance	32.17%
Interference and No Dominance	26.76%
Poor Level and No Dominance	0.00%
Poor Quality, Poor Level and No Dominance	0.02%

Table 6.14: Poor design reasons with their percentage for Kharoubeh area in October, 2011.

The interference now is lowered from 65% (Table 4.17) to 41% after the work in Jenien city.

6.4.8 Jabryat

For Jabryat area we will start by introducing Table 6.15 that shows the coverage classes and their percentages and compare these percentage with the old ones in Table 4.18:

1. 80.4% at level 1 now compared to 75.1% before the work started.
2. Level 4 the percentage is now increased from 4.37% to 5.22%. This is an increase of 0.85%. This occurred after the new activated site JENI26 which have a cell directed towards Jabryat area, and this cell reaches that area with poor quality. The future work in chapter 7, will discuss some suggested works on the new activated sites in Jenien city.
3. Level 2 is reduced from 12.1% to 9.8%.
4. Level 3 is also reduced from 8.3% to 4.5%.

RXLEVSUB/ RXQUALSUB	RXQUALSUB≤ 2	2<RXQUALSUB≤ 4	4<RXQUALSUB≤ 6	RXQUALSUB> 6	Any RXQUALSUB	Coverage Class	%
RXLEVSUB≥-70	80.42	4.39	3.90	3.41	92.12	Level 1	80.42
-70 ≥ RXLEVSUB ≥ -85	4.74	0.70	0.49	1.39	7.32	Level 2	9.83
-85≥ RXLEVSUB ≥-100	0.07	0.00	0.07	0.42	0.56	Level 3	4.53
RXLEVSUB ≤ -100	0.00	0.00	0.00	0.00	0.00	Level 4	5.22
Any RXLEVSUB	85.23	5.09	4.46	5.22	100.00	Total	100.00

Table 6.15: Percentage distribution of coverage classes of Jawwal GSM network in Jabryat area in October 2011

RXLEVSUB distribution is shown in Figure 6.36. This figure shows that this is a well covered area. The activation of the new site JENI26 also boosts the coverage at this area compared to the Figure 4.22 which shows the RXLEVSUB of Jabryat area before the work started. The average of RXLEVSUB for the collected samples in October, 2011 equals -58.23 dBm and the standard deviation equals 9.31.

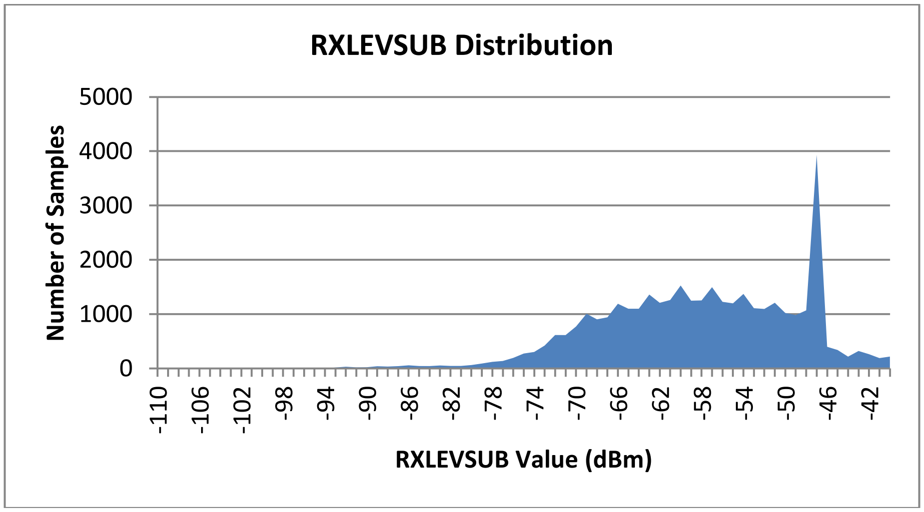

Figure 6.36: RXLEVSUB distribution in Jabryat area in October, 2011.

RXQUALSUB with value of 0 is now 79.5% compared to 69% before in August 2010 (Figure 4.23). For the poor RXQUALSUB samples which are now about 6% compared to 9.7% before the work started in Jenien city.

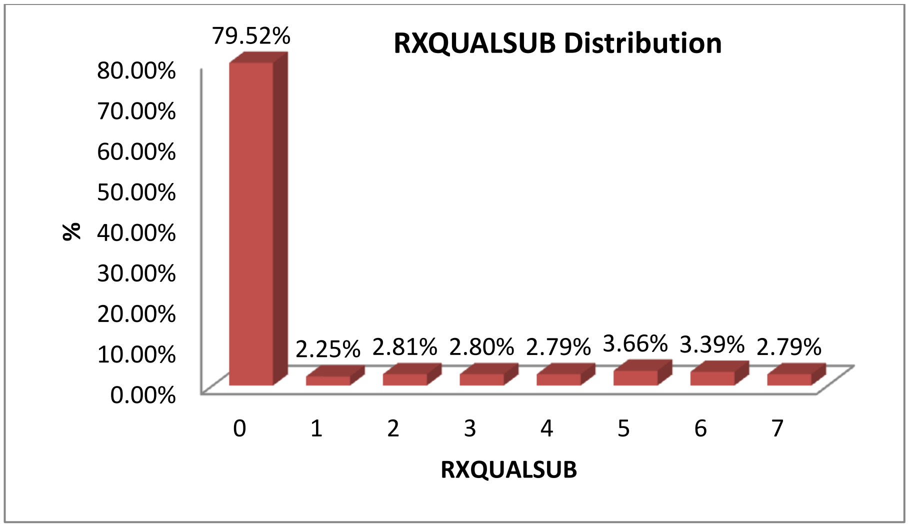

Figure 6.37: RXQUALSUB distribution in Jabryat area in October, 2011.

We are now going to check the reasons for poor design at Jabryat area and these reasons are presented on Table 6.16. The interference percentage is lowered from 75% (Table 4.19) to 31% after finishing all the work in Jenien city.

Cause	Percent
Interference	31.18%
Poor Level	0.45%
Poor Quality and Poor Level	1.65%
No Dominance	48.64%
Interference and No Dominance	16.91%
Poor Level and No Dominance	0.22%
Poor Quality, Poor Level and No Dominance	0.96%

Table 6.16: Poor design reasons with their percentage for Jabryat area in October, 2011.

6.5 Conclusion

Chapter 6 compares the performance of Jawwal GSM network in Jenien city before and after the conducting this research. It is concluded that:

1. The TCH drop rate for Jenien city cell set, which is the most critical KPI for both the operator and the customer, is reduced as shown in Figure 6.37.

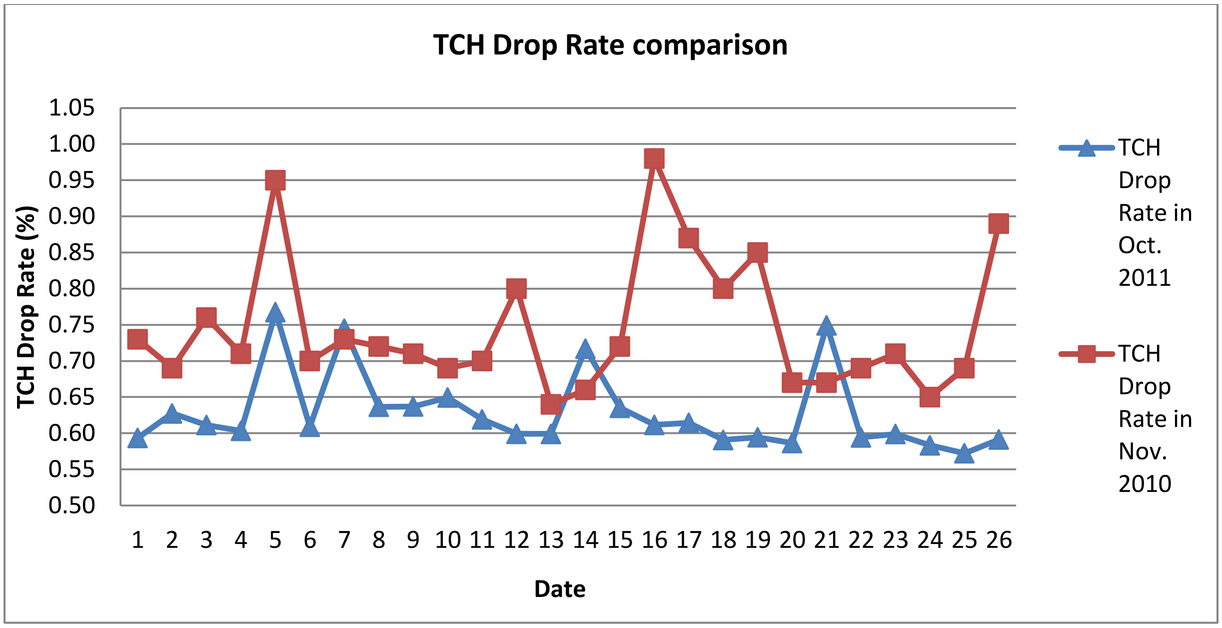

Figure 6.38: TCH drop rate comparison for Jenien city cell set between November 2010 and October, 2011.

From Figure 6.38, it is noted that the TCH drop rate in October, 2011 for the GSM cells in Jenien city is less than that in November, 2010. The average TCH drop rate for Jenien city cell set at November, 2010 was 0.745 % and at October, 2011 it is 0.62%.

2. The SDCCH drop rate for Jenien city cell set is also reduced as given by Figure 6.39.

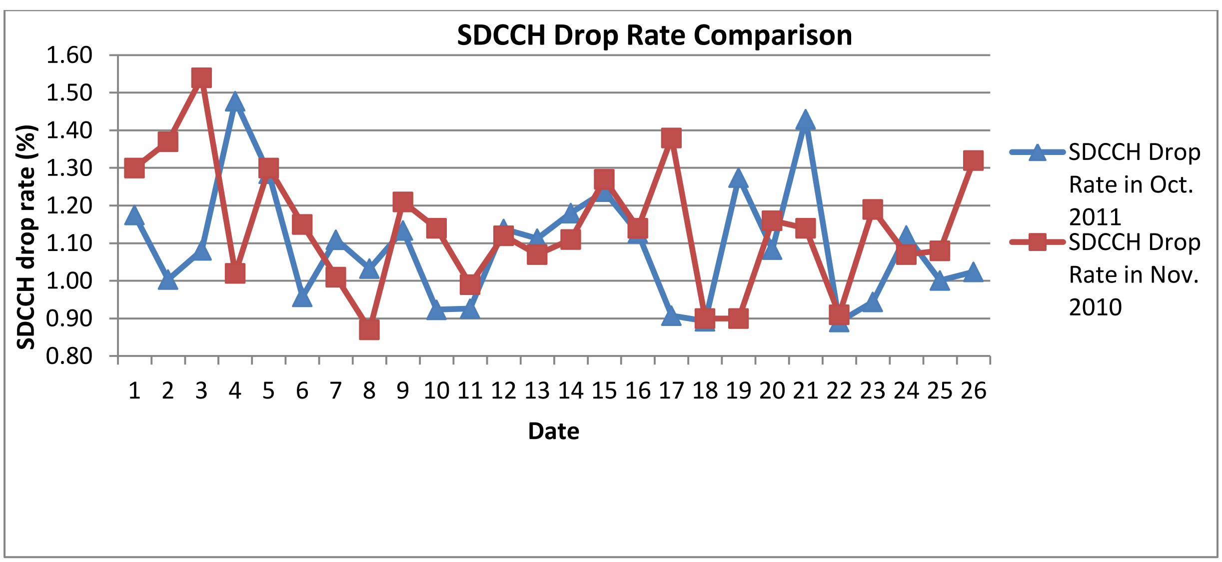

Figure 6.39: SDCCH drop rate comparison for Jenien city cell set between November 2010 and October, 2011.

The average SDCCH drop rate for Jenien city cell set was 1.14% in November, 2010. However, in October 2011 it is lowered to 1.06%.

3. TCH assignment success rate for Jenien city cell set is enhanced as reported in Figure 6.40.

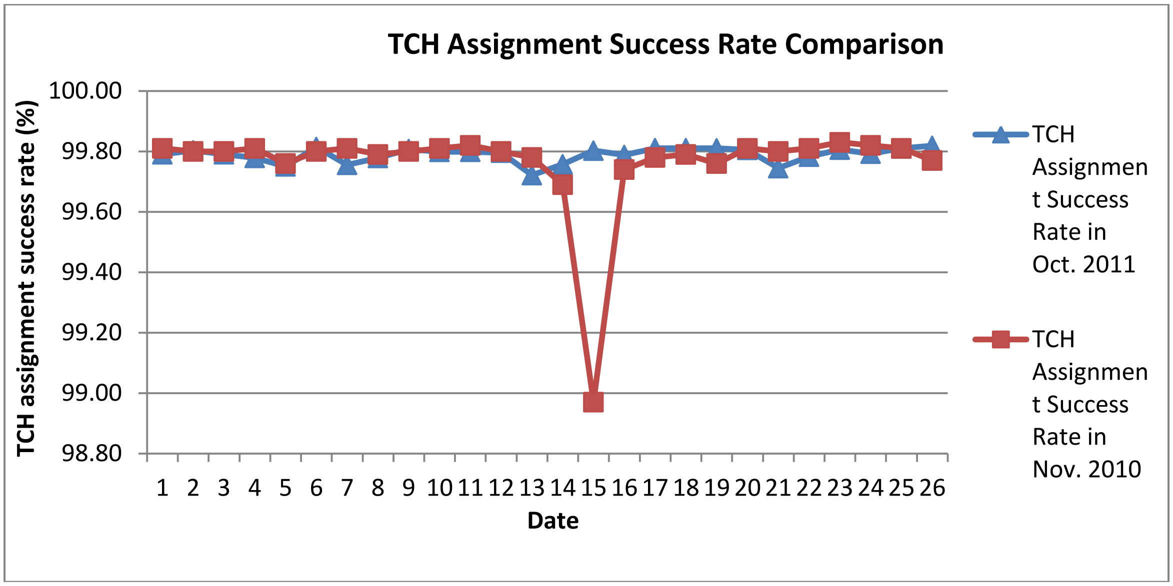

Figure 6.40: TCH assignment success rate comparison for Jenien city cell set between November 2010 and October, 2011.

The average TCH assignment success rate for Jenien city cell set was 99.76% in November, 2010. In October, 2011 it is enhanced to be 99.79%.

4. Handover success rate for Jenien city cell set is enhanced as noted in Figure 6.41. The average handover success rate for Jenien city cell set in November, 2010 was 95.75%. However in October, 2011 it is enhanced to be 96.13%.

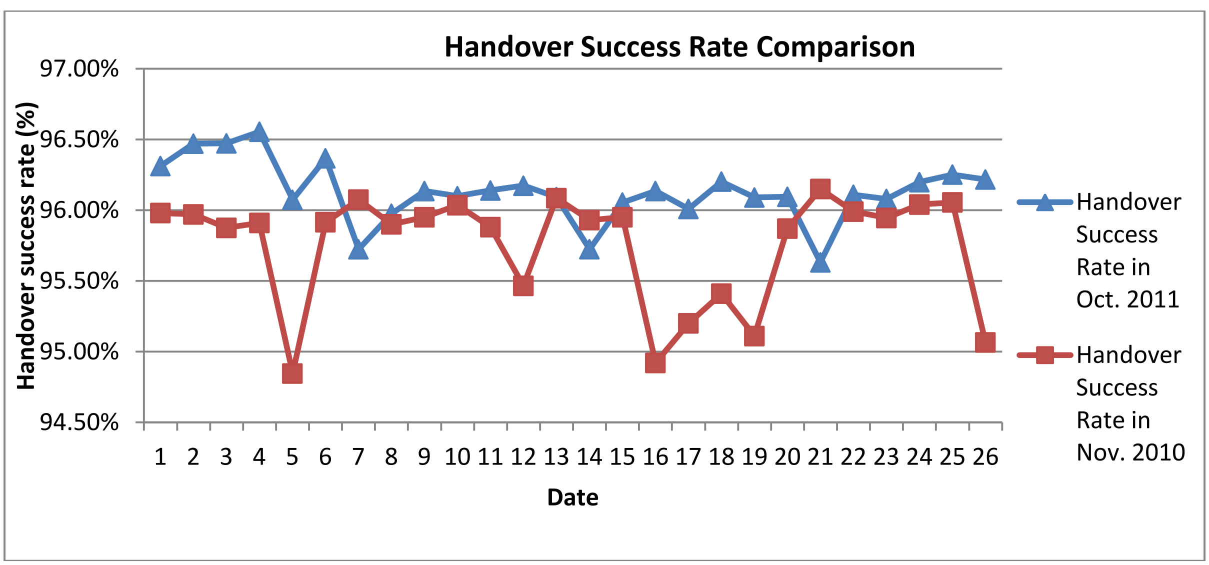

Figure 6.41: Handover success rate comparison for Jenien city cell set between November 2010 and October, 2011.

5. The percentage of the coverage classes for Jenien city in October 2011 shows good performance than those in August 2010 as given in Table 6.17 and Table 6.18.

    a) Level 1 is increased from 65% in August, 2010 to 76% in October, 2011.
    b) Level 4 is decreased from 7.76% in August, 2010 to 5.16% in October, 2011.
    c) Level 2 is reduced from 15.7% to 11.7%.
    d) Level 3 is also reduced from 11.1% to 6.38%.

RXLEVSUB/ RXQUALSUB	RXQUALSUB≤ 2	2<RXQUALSUB≤ 4	4<RXQUALSUB≤ 6	RXQUALSUB> 6	Any RXQUALSUB	Coverage Class	%
RXLEVSUB≥-70	65.46	6.97	7.56	4.99	84.98	Level 1	65.5
-70 ≥ RXLEVSUB ≥ -85	6.54	2.16	2.71	2.28	13.69	Level 2	15.7
-85≥ RXLEVSUB ≥-100	0.28	0.25	0.3	0.45	1.28	Level 3	11.1
RXLEVSUB ≤ -100	0.02	0	0	0.02	0.04	Level 4	7.76
Any RXLEVSUB	72.3	9.38	10.75	7.74	100	Total	100

Table 6.17: Coverage classes of Jawwal GSM network in Jenien City in August, 2010.

RXLEVSUB/ RXQUALSUB	RXQUALSUB≤ 2	2<RXQUALSUB≤ 4	4<RXQUALSUB≤ 6	RXQUALSUB> 6	Any RXQUALSUB	Coverage Class	%
RXLEVSUB≥-70	76.77	4.82	4.52	3.18	89.29	Leve1 1	76.77
-70 ≥ RXLEVSUB ≥ -85	5.71	1.17	1.69	1.81	10.38	Leve1 2	11.70
-85≥ RXLEVSUB ≥-100	0.07	0.05	0.05	0.17	0.34	Leve1 3	6.38
RXLEVSUB ≤ -100	0.00	0.00	0.00	0.00	0.00	Leve1 4	5.16
Any RXLEVSUB	82.55	6.04	6.26	5.16	100.00	Total	100.00

Table 6.18: Coverage classes of Jawwal GSM network in Jenien City during October, 2011.

6. RXLEVSUB distribution for Jenien city is better in October, 2011 than the one for August, 2010. This is obvious since activation of some sites takes place. This can be easily detected if the reader takes a look at Figures 6.42 and 6.43. Figure 6.43, demonstrates that the RXLEVSUB of all the samples are within -42 dBm and -85 dBm. While in Figure 6.42, it noted that there are number of samples beyond -85 dBm. The reader can note also that the average of RXLEVSUB collected samples in August, 2010 was -63.39 dBm and the standard deviation is 10.43. However, after the enhancement the average of the collected samples of RXLEVSUB in October, 2011 is -57.78 dBm and the standard deviation now is 9.06. It is noted that the RXLEVSUB now in Jenien city is better than in August, 2010 as obvious from the average value. Also for the standard deviation, it is noted that the values of RXLEVSUB are now close to the mean value more than before. This is because of the recently activated site in Jenien city.

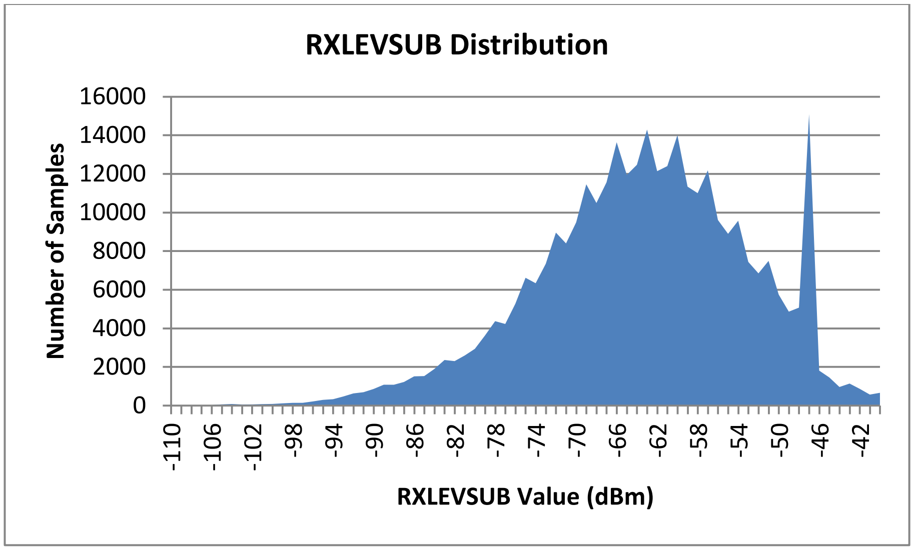

Figure 6.42: RXLEVSUB distribution of Jenien city in August 2010.

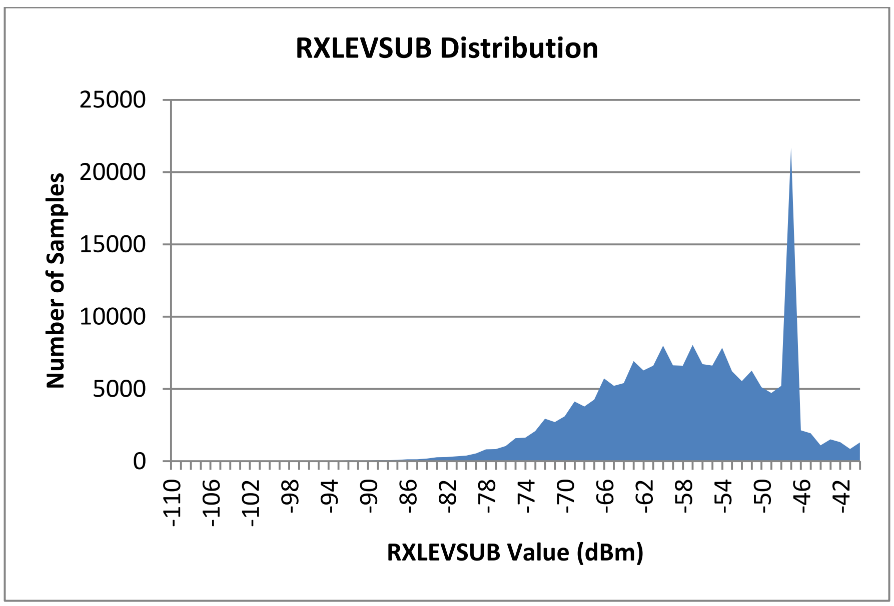

Figure 6.43: RXLEVSUB distribution of Jenien city in October, 2011.

7. RXQUALSUB distribution for Jenien city is also better in October, 2011 than the distribution in August, 2010. The RXQUALSUB with 0 value was 69% of the samples in August 2010. However, the RXQUALSUB with 0 value is increased to 76.75%. For the poor RXQUALSUB with value of 6 it was 5.88% in August, 2010 and it is reduced to 4.09% in October, 2011. The worst RXQUALSUB with value of 7 was 4.04% in August, 2010. And it is reduced to 2.61% in October, 2011 (Figures 6.44 and 6.45).

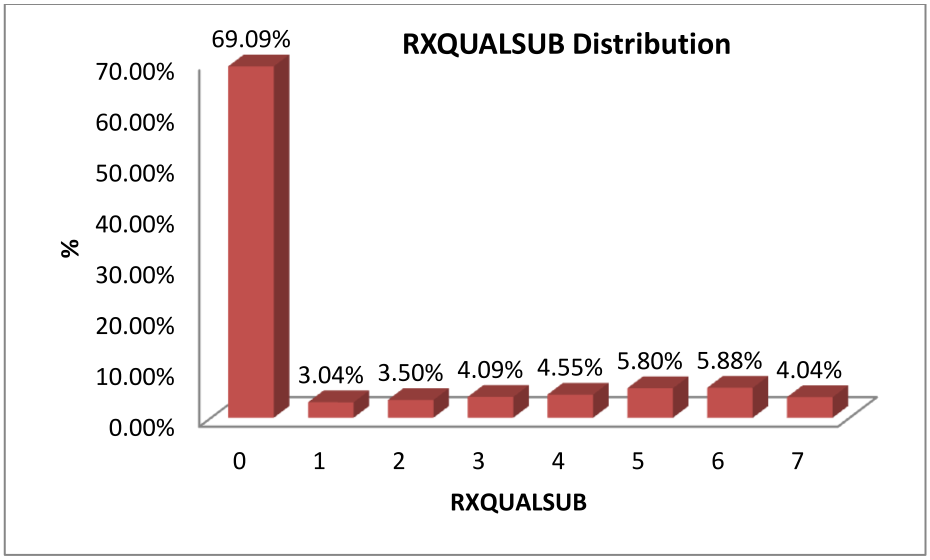

Figure 6.44: RXQUALSUB distribution of Jenien city in August 2010.

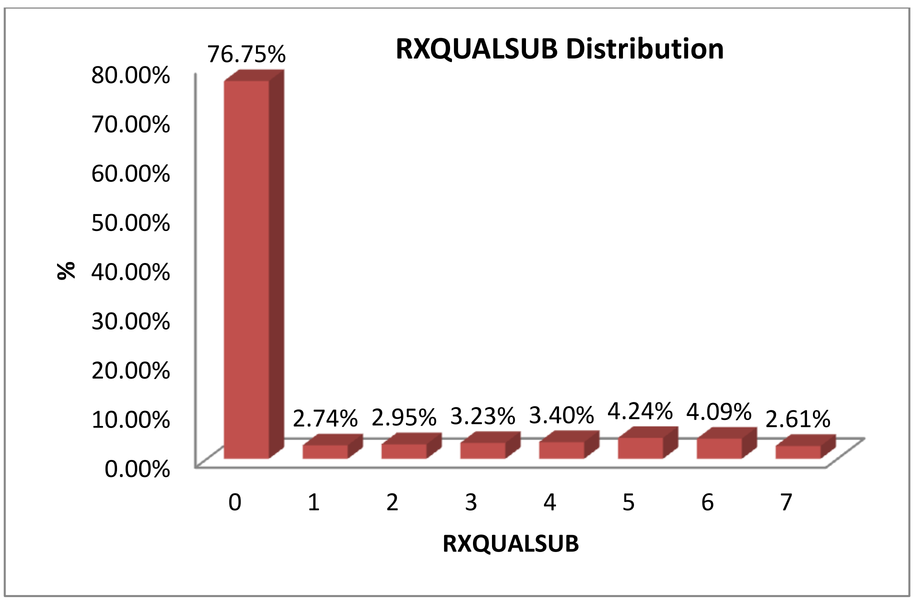

Figure 6.45: RXQUALSUB distribution of Jenien city in October, 2011.

8. The interference reason in the design validation process for Jenien city is lowered from 44.97% in August, 2010 to be 34.47% in October, 2011 as reported from Tables 6.19 and 6.20. While the no dominance is increased from 31.87% in August, 2010 to 46.55% in October, 2011. This issue will be discussed in chapter 7 in the section of future work.

Cause	Percent
Interference	44.97%
Poor Level	3.78%
Poor Quality and Poor Level	2.90%
No Dominance	31.87%
Interference and No Dominance	14.48%
Poor Level and No Dominance	1.03%
Poor Quality, Poor Level and No Dominance	0.96%

Table 6.19: Poor design reasons with their percentage for Jenien city in August 2010.

Cause	Percent
Interference	34.47%
Poor Level	0.20%
Poor Quality and Poor Level	0.65%
No Dominance	46.55%
Interference and No Dominance	17.57%
Poor Level and No Dominance	0.12%
Poor Quality, Poor Level and No Dominance	0.44%

Table 6.20: Poor design reasons with their percentage for Jenien city in October, 2011.

Chapter 7 will briefly discuss and conclude above results for this thesis. The future work to be done in Jenien city is also introduced in the next chapter.

Chapter 7

Conclusions and Future Work

7.1 Conclusions

In this thesis, a comprehensive research study is carried-out on the performance evaluation and enhancement of Jawwal GSM mobile network in Jenien city.

In chapter 1, the GSM system is introduced where a comprehensive literature survey about GSM network evaluation and optimization is conducted. Chapter 2 presents network audit for Jawwal GSM network in Jenien city. This network audit consists of: technical data about the current GSM sites, current BCCH frequency reuse, current TCH frequency reuse and current neighbor relation plan. According to this network audit, the 24 channels available to Jawwal are divided into 16 TCHs and 8 BCCHs. This results in high interference on the control channels as only 8 BCCHs are reused between all the cells of Jenien city.

In chapters 3 and 4, two methods for the evaluation of Jawwal GSM network are presented, which are the KPIs and the drive tests. The most common KPIs for Jawwal GSM cells in Jenien city are collected. The worst performing cells in these KPIs are then identified. In addition, the drive test for seven areas in Jenien city are collected and analyzed. From chapter 3 and chapter 4, it is concluded that the co-channel interference is the major issue in Jawwal network which greatly affects the QoS. Also, it is concluded that there is high level of interference on the BCCH frequencies. This is a direct result of having sites with high configuration (each site consists of 3 cells with 6 TRUs each). For these sites, 16 channels of the total 24 channels are used as TCHs. This will keep only 8 channels used as BCCH.

In chapter 5, the optimization process of Jawwal GSM network is introduced. It consists of two stages which are: First, the manual optimization process which starts with capacity analysis and neighbor relation plan is presented. Detailed capacity analysis is carried out to find the optimal number of TCHs without causing congestion. It is found that 12 TCHs is the best choice in order to carry the peak traffic that is ever carried by each GSM cell in Jenien city. Thus, 12 ARFCNs from a total of 24 ARFCNs are used as BCCHs. New initial frequency plan for both BCCH and TCH are then suggested. Also a new neighbor relation plan is proposed manually. These initial plans are then implemented and the performance of Jawwal GSM network is evaluated showing better results in terms of TCH drop rate and SDCCH drop rate. Following the manual optimization process, a second optimization process is carried out by using OSS optimization tools. These optimization tools are used to fine tune the proposed frequency and neighbor relation plan. Thus, another frequency plan is proposed for both BCCH and TCH using FAS. The OSS tools guarantees that each GSM cell in Jenien city is configured for the best BCCH and TCH plans with the lowest interference. NCS is then used to fine tune the initial proposed neighbor relations plan and to find missing or extra neighbor relations for each cell.

In chapter 6, another round of KPIs collection and drive tests are carried out so as to compare the performance of Jawwal GSM network before and after carrying out this research. Then comparative study shows that the performance of Jawwal GSM network in October, 2011 is better than the performance that we have started with in August, 2010 in terms of TCH drop rate, signal level and signal quality. Indeed, the average TCH drop rate is reduced from 0.745% to 0.62%. In addition, the percentage of the samples in level 4 (which corresponds to poor signal strength and quality) was reduced from 7.76% to 5.16% while the percentage of the samples in level 1 (which corresponds to excellent signal strength and quality) is increased from 65.5% to 76.77%. Moreover, the SDCCH drop rate was reduced from 1.14% to 1.06%. Furthermore, the TCH assignment success rate is improved from 99.76% to 99.79 and the handover success rate is improved from 95.75% to 96.13.

7.2 Future Work

Final evaluation and comparative study is the last step in this research after carrying out the optimization phase for Jawwal GSM network in Jenien city. The evaluation that is done by using KPIs and drive test analysis show that better performance for Jenien city cell set is achieved after this work in Jenien city is finished. However, there is extra work that can be done to enhance the performance of Jawwal GSM network in Jenien city even better. From the following two fields, better performance for Jenien city can be achieved.

1. Enhancing the performance of the new integrated sites such as sites JENI24, JENI26, JENI27, JMIC03 and JMIC06. This evident from the fact that the cell JENI26A is the worst performing cell in Jenien city in terms of TCH drop rate with more than 3.5%. The work on these new sites will contain physical modifications to serve their objectives with good QoS. The physical modifications may include changing cell azimuth, antenna type, antenna tilt, antenna height, etc.

2. From Table 6.20, it is noted that the interference is now reason number two in making poor performance for Jawwal GSM network in Jenien city. While no dominance is now ranked as reason number one that is responsible for the poor performance in Jenien city with about 46%. As mentioned earlier, the no dominance occurs when there are two or more neighbor cells within 5dB deviation from the serving cell. This issue is typical in GSM networks and it results in ping pong handovers which makes poor QoS during the connected mode. The drive test for each area in Jenien city could be investigated to find the best cell that can serve a desired objective. The best cell can be strengthened or the other cells can be weakened to reduce the effect of no dominance.

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