School of Engineering and Design

Performance Measurements and Analysis of the Existing Wireless Communication Technology in Iraq.

Kassim Mohammed Al-Hassani
Student Number: 0939718

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Abstract

Iraq may be considered as the largest wireless market in the Gulf region. A key driving factor in the market of wireless communication, it has seen enormous growth in the mobile phone market over the last five years leading to almost 24 million subscribers in 2011. Moreover, there are several technologies and services working in Iraq; three GSM Operators, three CDMA national operators and three CDMA provinces operators. The recent growth in the mobile phone market is based on the Global System for Mobile (GSM) communications and Code Division Multiple Access (CDMA) standards creating the next-generation wireless technologies in the Iraqi Wireless Communication market.

One of the essential issues of this research is to investigate the performance of the decreased Quality Of Service (QoS) caused by interferences in the services on GSM/CDMA operators in Iraq. Many issues should be studied and taken into consideration, such as; does the Multi-Coalition Forces cause the interferences, jamming, higher rate of calls drop and false ringing; or are they caused by bad design and planning? Do we need to optimise our network due to the large number of users? All these factors are investigated and the measurements of most service providers and government agencies will be gathered. A detailed analysis was included from the providers with measurements of performance and the reasons for the deterioration of wireless services.

The novel contributions of this thesis is the extensive radio measurement campaign over the three mobile an CDMA operator networks and the analysis and recommendations that were drawn to suggest the best approach to improve the QoS of Wireless communication technologies. Awareness of actual reasons behind the deterioration of services will be raised to the Iraqi Government, CMC and the wireless service providers.

Declaration

This is to certify that:

(i) the thesis comprises only my original work towards the PhD except where indicated,

(ii) due acknowledgement has been made in the text to all other material used,

(iii) the thesis is less than 100,000 words in length, exclusive of table, maps, bibliographies, appendices and footnotes.

Kassim Mohammed Al-Hassani

Conference Participations

During the course of this project, a number of public presentations have been made which are based on the work presented in this thesis. They are listed here for reference.

Kassim. M. Al-Hassani, Prof. John Cosmas, **"Assessing physical infrastructure requirements; pioneering partnership models",** 8th Iraq Telecoms Conference, Istanbul, Turkey, October 2013.

Kassim M Al-Hassani , Prof. John Cosmas **"Eurasian market overview: identifying new business opportunities in key Eurasian growth markets",** Eurasia Conference, Istanbul, Turkey, September 2013.

Kassim M Al-Hassani , Prof. John Cosmas **" Cyber Security Policy Changes for Today's Threat Environment**", 2nd e@iraq conference 2013, Baghdad, Iraq, April 2013.

Kassim. M. Al-Hassani, Prof. John Cosmas , "**New Carrier Business Opportunities in Iraq: Examine the existing infrastructure and identifying where development is needed"** Capacity Middle East 2013, Dubai, UAE, March 2013.

Kassim. M. Al-Hassani, Prof. John Cosmas **,"Internet for All: Opportunities & Challenges"** 7th Iraq Telecoms Conference, Istanbul, Turkey, November 2012.

Kassim. M. Al-Hassani, Prof. John Cosmas, **"Revolutionising Iraq with New Technological Applications "**, 7th Iraq Telecoms Conference, Istanbul, Turkey, November 2012.

Kassim M Al-Hassani , Prof. John Cosmas **"Submarine Cable and Transit Strategy for Successful Enhancing Capacity Demand – Upgrading Existing Infrastructure Vs. New Fiber**", e@iraq conference 2012, Baghdad, Iraq April 2012.

Kassim. M. Al-Hassani, Prof. John Cosmas **" Regulatory Round Table: Driving competition while increasing innovation Broadband MEA Driving Sustainable Growth of Broadband in the MEA region**", Dubai, UAE, March 2012

Kassim. M. Al-Hassani, Prof. John Cosmas "**OIL & GAS wireless communications & facilitating requirements and Systemic licensing challenges**",SMi 5th annual conference on Oil and Gas Communications Understanding the importance of satcomm and telecommunication channels, London, UK, March 2012.

Kassim. M. Al-Hassani, Prof. John Cosmas , Safaa Jassim "**Measuring The Pace of access Infrastructures Development in key Middle East Growth markets to meet demand for Broadband" ,** Capacity Middle East 2012, Dubai, UAE, February 2012.

Kassim. M. Al-Hassani, Prof. John Cosmas "**Positioning Iraq as a Transit Hub For International Traffic Through Fibre Investment"**, Telecoms World Iraq Conference, Dubai, UAE, October 2011.

Kassim. M. Al-Hassani, Prof. John Cosmas, Safaa Jassim "**New Opportunities & Perspectives: Internet, broadband penetration**", 6^{th} Iraq Telecoms Conference, Istanbul, Turkey, October 2011.

Kassim M Al-Hassani , Prof. John Cosmas, "**Technology progress: new application for the Iraqi market: end-user real needs and impact on business and public services**", 6^{th} Iraq Telecoms Conference, Istanbul, Turkey, October 2011.

Kassim M Al-Hassani , Prof. John Cosmas "**Restructuring business to cope with an increasingly competitive market**", **,UK ,London ,onferenceCarriers World Europe C .2011September**

Kassim M Al-Hassani , Prof. John Cosmas "**Evaluating The Role of Eurasia as a Bridge Between Europe, The Middle East and Asia",** Eurasia Conference, Istanbul, Turkey, September 2011.

Kassim M Al-Hassani , Prof. John Cosmas "**FTTx Deployments in Iraq: Creating a Brighter Future**"., Iraq FTTx Conference, Beirut, Lebanon, June 2011.

Kassim M Al-Hassani , Prof. John Cosmas "**FTTH Investment in Iraq: Golden Opportunity**". Iraq FTTx Conference, Beirut, Lebanon, June 2011.

Mohammed Al-Momin, John Cosmas, Kassim Al-Hassani, and Safaa Jassim, **"Policy Based Management of Optical Fibre Networks Carrying Multiple Application Traffic",** Second Communications Conference held by the Ministry of Communications in Baghdad, IRAQ in cooperation with IEEE-IRAQ SECTION. It has been accepted and awarded a trophy. 14-16 March 2011.

Kassim M Al-Hassani , Prof. John Cosmas "**Case Study: Why Deploying FTTH in Iraq**", The FTTH Council Middle East, Beirut, Lebanon, November 2010

Kassim M Al-Hassani , Prof. John Cosmas "**Iraq's Telecoms Potential; Private Public Partnership & Government Policies**", 5th Iraq Telecom Conference, Istanbul, Turkey, October 2010.

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Abbreviation

3G: Third Generation

3GPP: Third Generation Partnership Project

4G: Fourth Generation

ABS: Asia Broadcast Satellite

ACELP: Algebraic Code Excited Linear Prediction

ADSL: Asynchronous Digital Subscriber Line

AFRN: Automated First Responder Network

AM: Amplitude Modulation

APCO: Association of Public –safety Communications Officials

AQM: Audio Quality Measurements

ANSI: American National Standard Institute

ARFCN: Absolute Radio-Frequency Channel Number

ASON: Automatic Switched Optical Network

ASTN: Automatic Switched Transport Network

ATEX: Atmospheres Explosives

BCCH: Broadcast Control Channel

BGAN: Broadband Global Area Network

BGP: Border Gateway Protocol

BMI: Business Monitor International

BP: British Petroleum

BRIC: Brazil Russia India China

BTS: Base Transceiver Station

BU: Branch Unit

CAD: Computer Aided Design

CAPEX: Capital Expenditures

CAVE: Cellular Authentication and Voice Encryption

CATV: Cable Television

CBI: Central Bank of Iraq

CCIR: International Radio Consultative Committee

CCITT: International Telegraph and Telephone Consultative Committee

CCTV:Closed-Circuit Television

CDMA: Code Division Multiple Access.

CDN: Computer Data Network

CEO: Chief Executive Officer

CEPT: European Conference of Postal and Telecommunications Administrations

C/I: Co-channel Interference

CLS: Cable Landing Stations

CMC: Communications and Media Commissions

CNA: CDMA Networks Analysis

CNT: CDMA Network Testing

CPA: Coalition Provisional Authority

CPC: Coalition Provisional Communication

CPE: Customer Premises Equipment

CRS: Carrier Routing System

CTnet: Counter Terrorism Network

CTO: Chief Technology Officer

DL: Down Load

DMS: Document Management system

DMVPN: Dynamic Multipoint Virtual Private Networking

DSL: Digital Subscriber Line

DT: Drive Testing

DTX: Discontinuous Transmission

DVB: Digital Video Broadcasting

DWDM: Dense Wavelength Division Multiplexing

ECC: Elliptic Curve Cryptography

EC/IO: Energy to Interference

EDGE: Enhanced Data for GSM Evolution

EPC: Evolved Packet Core

ERC: European Radio Communications Committee

ETSI: European Telecommunications Standards Institute

EVDO: Evolution Data Only/Evolution Data Optimised.

EVRC: Enhanced Variable Rate Codec

FDM: Frequency Division Multiplexing.

FDMA: Frequency Division Multiple Access.

FE: Fast Ethernet

FER: Frame Erasure Rate

FHMA: Frequency Hopping Multiple Access.

FLAG: Fiber Link Around the Globe

FM: Frequency Modulation

FMC: Fixed Mobile Convergence

FTP: File Transfer Protocol

FTTB: Fiber To The Building/Business

FTTC: Fiber To The Curb

FTTH: Fiber To The Home.

FTTx: Fiber To The x

GBI: Gulf Bridge International

GBICS: Gulf Bridge International Cable System

GCC: Gulf Cooperation Council

GDP: Gross Domestic Product

GE: Gigabit Ethernet

GES: Global Experience Specialists

GIS: Geography Information System

GIT: Gulf Iraq Turkey

GLA: Ground Level Altitude

GMPLS: Generalised Multi Protocol Label Switching

GNOC: Global Network Operations Centre

GOI: Government of Iraq

GOIC: Government of Iraq Council

GoTa: Global Open Trunking Architecture

GPRS: General Packet Radio Service

GPS: Global Positioning System

GSM: Global System for Mobile

HD: High Definitions

HSPA: High Speed Packet Access.

HTTP: Hypertext Transfer Protocol

I2N: Iraqi Intelligence Network

IC2N: Iraq Command and Control Network

ICT: Information and Communications Technology

IDN: Iraqi Defence Network

IDEN: Integrated Digital Enhanced Network

IDSN: Integrated Services Digital Network

IED : Improvised Explosive Device

IEEE: International Electrical and Electronic Engineer

IGW: International Gateway

IIBN: Iraqi Inter Banding Network

ILD: International Long-Distance.

ILEC: Incumbent Local Exchange Carrier

IMBE: Improved Multi Band Excitation

IMS: IP Multimedia Subsystems

IMT: International Mobile Telecommunications.

INIC: Iraqi National Investment Commissions

INIS: International Nuclear information System

IP: Internet Protocol.

IPSec: Internet Protocol Security

IPTV: Internet Protocol Television

IQ: Iraq

IQD: Iraqi Dinar

IS-95: Interim Standard 95

ISDN: Integrated Services Digital Network

ISP: Internet Service Provider

IT: Information technology

ITPC: Iraqi Telecommunications and Post Company

ITU: International Telecommunication Union.

ITU-T: International Telecommunication Union-Telecommunication Standardisation

IVR: Interactive Voice Response

IXP: Internet exchange Point

IZFN: International Zone Fiber Networks

KPI: Key Performance Indicator

KRG: Kurdistan Regional Government

LAN: Local Area Network

LH: Long Haul

LMDS: Language Materials Distribution System

LTE: Long Term Evolution

MAC: Machine Access Code

MAN: Metropolitan Area Network

MENA: Middle East and North Africa

MHL: Mobile High Definition Link

MIMO: Multiple Input Multiple Output

MMDS: Microwave Multi-point Distribution System

MMS: Multimedia Messaging Service

MMSE: Minimum Mean Square Error

MNF: Multi National Forces

MOC: Ministry Of Communication

MOD: Ministry of Defence

MODnet: Ministry of Defence Network

MOI: Ministry of Interior

MOInet: Ministry of Interior Network

MOS: Mean Opinion Score

MOST: Ministry of Science and Technology

MOU: Memorandum Of Understanding

MPBN: Mobile Protocol Backbone Network

MPEG: Moving Picture Experts Group

MPLS: Multi Protocol Label Switching

MNC: Multinational Cooperations.

MTC : Mobile Telecommunications Company

MW: Microwave

NAT: Network Address Translation

NCMC: National Communication and Media Commission

NGN: Next Generation Network

NIPRnet: Internet Protocol Router Network

NMEA: National Marine Electronics Association

NMS: Network Management System

NOC: Network Operations Centre

NT: Newroz Telecom

NZDSF: Non-Zero Dispersion Shift Fiber

OADM: Optical Add-Drop Multiplexer

OFDM: Orthogonal Frequency Division Multiple Access.

OFDMA: Orthogonal Frequency Division Multiple Access.

OMC: Omnicom Group

OMS: Optical Multi Service

OPEX: Operational Expenditure

OSN: Optical Service Network

OTN: Optical Transport Network

OW: Order Wire

PBX: Private Branch exchange

PC: Personal Computer

PCMCIA: Personal Computer Memory Card International Association

PCS: Personal Communication System

PESQ: Perceptual Evaluation Speech Quality

PFE: Power Feed Equipment

PING: Packet INternet Groper

PIX: Private Internet Exchange

PMP: Point to Multi Point

PN: Projection Neurons

POP: Point of Present

PPP: Point-to-Point Protocol

PSC: Premises Splice Cabinet

PSTN: Public Switches Telephone Network

PTT: Push To Talk

QAM: Quadrature Amplitude Modulation

QoQ: Quarter On Quarter

QoS: Quality of Service

QPSK: Quadrature Phase Shift Keying

RAMAN: Regional Atmospheric Measurement and Analysis Network

RF: Radio Frequency.

RFS: Ready For Service

ROADM: Reconfigurable Optical Add-Drop Multiplexer

RS-232: Recommended Standard 232

RSSI: Received Signal Strength Indication

SAIT: Saudi Arabia Iraq Turkey

SCIS: State Company for Internet Services

SCPC: Single Carrier Per Channel

SDH: Synchronous Digital Hierarchy

SIR: Standardised Interconnections Requirements)

SLA: Service Level Agreement

SLTE: Submarine Line Terminal Equipment

SMS: Short Message Service

SME: Small and Mid-sized Enterprise

SNCP: Sub networks Connection Protection

SOHO: Small Office Home Office

SQI: Speech Quality Index

SSD: Shared Secret Data

STC: Saudi Arabia Telecoms Company

STM:Synchronous Transport Module

TCP: Transmission Control Protocol

TCP/IP: Transmission Control Protocol/Internet Protocol

TCL: Tata Communication Ltd

TDD: Time Division Duplex

TDM: Time Division Multiplexing

TDMA: Time Division Multiple Access

TD-SCDMA: Time Division-Synchronous Code Division Multiple Access

TEMS: Telecommunications Expense Management Services)

TETRA: TErrestrial Trunked Radio

TGN: Total Global Network

TGN-EA: Total Global Network-Europe Asia

TISPAN: Telecommunications and Internet Converged Services and Protocol.

UAE: United Arab Emirates

UDP: User Datagram Protocol

UL: Up Load

ULL: Ultra Low Loss

UMTS: Universal Mobile Telecommunication System

UN: United Nations

USA: United State of America

VOIP: Voice Over Internet Protocol

VPM: Varying Permeability Model

VPN: Virtual Private Network

VSAT: Very Small Aperture Terminal

VSELP: Voice Sum Excited Linear Predictive

VTC: Video Teleconferencing

WAP: Wireless Datagram Protocol

WBB: Wireless Broad Band

WBBN: Wireless Broadband Networks

WCDMA: Wideband Code Division Multiple Access

WI-FI: Wireless Fidelity

WIMAX: Worldwide Interoperability for Microwave Access

WLAN: Wireless Local Area Network

WLL: Wireless Local Loop

XPIC: Cross Polarization Interference Cancellation

ZXPOS: ZTE Network Planning and Optimisation System

Chapter One

1.0 Background and Research Outline

1.1 Introduction

The Republic of Iraq is located in the Middle East, bordering Turkey from North, Iran from East, Kuwait, Saudi Arabia and the Arabian Gulf from South and Jordan and Syria from the West.
The country has 438 000 sq km total area and the population in 2009 estimated 31.2 million. Baghdad is the capital of Iraq, having a municipal population estimated at 7 million i.e. the largest city in Iraq.

Iraq telecommunications sector has been significantly damaged as a result of conflict and economic sanctions of the 20 years preceding the 2003 war. During this time, rapid advancements in telecommunications technology did not reach Iraq and the country fell far behind global telecommunications standards.

In the 1980's Iraq had a solid telecommunications infrastructure, some of which was installed by France's Alcatel. Improvements and expansions to this system, however, were delayed or abandoned due to increases in the military's budget during the same decade. In 1990, international economic sanctions were imposed which limited the country's ability to obtain technology systems, equipment and spare parts so that by time the regime changes in 2003, Iraq was far behind global telecom standards. [INIC, 2009]

By 2003, the fixed-line telephone was quite limited and a nationwide telecommunications market did not exit. Today, Iraq Telecom sector is one of the fastest growing markets in the region, with the private sector one of the primary drivers of this growth according to the Arab Advisory Group's 2009 cellular competition intensity index reveals that Iraqis the most competitive Arab cellular market. Jordan, which was the most competitive market in the 2007 and 2008 indexes, came in second.

The Cellular competitions intensity index results for 2009 revealed that Iraq tops the score as the most competitive Arab market with 91.0% mark followed by Jordan (82.7%), Saudi Arabia (79.2%), Palestine (78.6%), Egypt (69.8%), Morocco (67.7%), Algeria (64.6%), Tunisia (51.5%), UAE (50.2%), Oman (44.8%), Libya (35.7%), Syria (34.2%), Lebanon (33.6%) and finally Qatar (31.5%). [The Arab Advisor Group, 2009].

“Iraq's performance was excellent in the Cellular competition intensity index ranking first with score as high as 91.0% and dethroning Jordan. There are five working operators in the country, three of which operate a national mobile license, while the remaining two are regional operators operating in Kurdistan region. While Iraq's largest operator (Zein) has a substantial market share of more than 50%, Iraq's score benefited from the availability of corporate offers, operational ILD (International Long Distance) competition and 3G services. "Mr. Andrawes Snobar, Arab Advisors' Research Manager.

The Information and Communications Technologies (ICT) sector for Iraq has undergone three phases in recent years :

1. Prior to 2003, the sector showed sluggish growth in the fixed line and mobile sectors in the absence of a regulator. Internet penetration remained weak throughout Iraq. More

   Sophisticated uses of ICT in applications and services for business, government and society were not common. Iraq was the only country in the Middle East that did not have a national cell phone network. In the 1980's, the country had a national fixed-line density rate of 5.6%. As economic sanctions prohibited the import of spare parts, the telephone system experienced rising problems after 1990. For most Iraqi's, it was difficult to call between provinces from fixed-line phones and breakdowns were common especially in periods of heavy rain. Many callers also experienced interferences with multiple phone conversations audible on the same line. By 2002 density rates had dropped to 3.7%.

2. Between 2003 and 2007, a regulator was established under Order 65 of the Coalition Provisional Authority (CPA). In recognition of the growing importance of the telecommunications sector, the Government of Iraq opted to separate the Ministry of Transportation and Communications in two separate ministries in 2004.

   Mobile sector was opened up to private sector with the issuance of three mobile licenses. Mobile penetration reached unprecedented levels during this period. The institutions constituting the sector were reorganised so the influences of a command-and-control economy established prior to 2003 were reduced. "By January 2006, the number of fixed lines amounted to around 1.2 million lines, with a penetration rate of 4.4%. The bulk of fixed lines subscribers are based in Iraq's capital: Baghdad, which has close to 40% of the total lines in the country. In regards to the cellular market, the total number of subscribers in Iraq stand at around 8.7 million subscribers by Q3 2006, when adding around 1.2 million subscribers from the two regional operators: Korek Telecom and SanaTel. Consequently, on September 30, 2006,the cellular penetration rate in Iraq stood at around 31.4%.

3. Since 2007, Iraqi Ministry of Communications (MoC) has developed a new policy to further modernise the communications sector, strengthen the institutions comprising the communications sector, attract private sector participation, and bring improved applications and services for the citizens of Iraq. The Iraqi Telecommunication market enters a whole new competitive era in 2007 by launching of multiple wireless fixed services providers. The country also has competition between three national cellular operators and two regional ones. The CMC awarded licenses for the provision of local telecommunications services through the deployment of wireless local loop (WLL) technologies to three National licenses and two provinces licenses.

1.2 Sector Institutions

There are two government bodies that oversee telecommunication sector and licensing in Iraq, the CMC and the Ministry of Communication (MoC). The CMC is the primary regulatory body in Iraq and is charged with defining regulations for telecom and media promulgating policy for frequency management and licensing wireless and telecommunication services. The CMC is Iraq's first independent media and telecommunication regulator.

1. The sector consists of the following institutions:
   a) Ministry of Communications (MoC).
      Iraqi Telecommunication and Post Company (ITPC)
      State Company of Internet Services (SCIS)
   b) Communications and Media Commission (CMC).
   c) Private mobile operators (GSM, WLL, WiMax, ISP)

2. MoC has the following role in the sector:
   a) Development, implementation and coordination of sector policy.
   b) International Voice and Data Gateway (IGW).
   c) Provisioning of an enabling environment for investment in the sector.
3. CMC has the following role in the sector:
   a) Regulatory body for the sector.
   b) Spectrum management and assignment.
   c) Licensing Private operators e,g, (GSM, WiMax, WLL).
4. ITPC acts as the incumbent operator of the sector within Iraq.

1.3 Sector Organisation

1. The communications sector of Iraq can be sub-divided into four categories:
   a) <u>Fixed communications</u>: including fixed telephone networks, switches and wireless local loop networks (WLL).
   b) <u>Mobile communications</u>: including mobile operators.
   c) <u>Internet and computing</u>: including internet services, internet cafes, Wireless Broadband, Wifi, WiMax, internet exchange, VTC, IP network and e-government.
   d) <u>Telecom infrastructure</u>: including fiber optic networks, microwave backbones, submarine cables, international gateways, communications buildings and real estate, the Telecom Institute and security communications.

1.4 Fixed Communications

Iraq’s fixed-line network was severely damaged in 2003 and fixed-line density had deteriorated. In the 1980’s, the country had a national fixed-line density rate of 5.6%. This had dropped to approximately 3.5% in 2002. By comparison, in 2001 Egypt had 32% density in residential lines, Jordan had 56% density and Kuwait had 130% density, the latter reflecting that many Kuwaiti homes apparently had multiple lines [MTC communications, 2006].

As economic sanctions prohibited the import of spare parts, the telephone system experienced rising problems after 1990. For most Iraqis, it was difficult to call between provinces from fixed-line phones. In addition, breakdowns were common, especially in periods of heavy rain. Many callers also experienced interference, with multiple phone conversations audible on the same line [MTC communications, 2006].

Within fixed communications, Iraq has reached the following milestones until 2009:

a) Fixed lines have exceeded 1.2 million.

b) A next-generation network (NGN) is being deployed to provide another 740 thousand fixed lines.

1.5 Mobile Communications

For many years, the former regime was reluctant to allow cell phone use in Iraq, considering it a security threat. By the time the attitudes changed enough for Iraq to purchase a cellular phone network, sanctions prevented the government from obtaining one.

In 2003, the Government issued three temporary regional cellular phone licenses, roughly corresponding to the three geographical areas of north of Iraq, centre and south. These licenses were later converted to national licenses, and were set to expire in December 2005. The Ministry of Communications extended these licenses for an additional six months, and made plans to issue up to four 15-year national licenses in 2006.

These first licenses allowed Iraqis to obtain cellular phone service, but they were not without challenges. The three systems were not initially integrated, so that callers

with in one region had difficulty calling phone customers in another part of the country. As a result, as of early 2006 some Iraqis still carried three cellular phones, one for each service provider, in order to have reliable service throughout the country. Iraqis were able to obtain personal cellular phone numbers and devices for the first time in 2004. By the end of that year, the country had 1.3 million new subscribers. By the end of 2005, estimated domestic subscribers numbered 3.45 million.

In spite of the widespread adoption of mobile phone technology in Iraq since 2003, market penetration for both fixed-line and mobile telephones remains low.

Mobile market density stood at 12.5% at the end of 2005. The NCMC will issue up to four 15-year national mobile telephone licenses in 2006 but the didn't till August 2007; it is hoped that a competitive market will improve service and bring down the cost.

In summary within mobile communications (GSM and CDMA), Iraq has reached the following milestones until 2011:

1. a) Mobile subscribers have exceeded 20 million Subscribers by end of 2011.
   b) August 2007 three GSM licenses have been issued to private operators at a price of US $ 1.25 billion per license and a revenue sharing facility of 18% (equalling approximately US $ 1.8 billion) per license. These licenses are privately held and have been formed as joint ventures with foreign operators.
   c) Networks operators have concentrated on covering the most populated and lucrative parts of Iraq.
   d) Service availability and quality has been unsatisfactory.
   e) No monitoring or enforcement of performance targets stated in the license due to the inactive regulator in Iraq.
2. a) CDMA total subscribers approx. less than one Million.
   c) Three CDMA National licenses issued to the private sectors.
   d) Four regional licenses also on operations in Iraq including one in Kurdistan region.
   e) ITPC one of the three CDMA National licenses holder and outsource to other two operators to operate under ITPC license. (See table 1).

Table 1: CDMA Current Operators in Iraq

License Type	Company	Provinces	Issued by
National	Itasaluna	All Iraq *	CMC
National	Kalimat	All Iraq *	CMC
National	ITPC	Baghdad,Najaf, Diyla,Karbala, Tikret	CMC
Provinces	ITPC/Omnea	Basarh, Nasriya, Samawa, Dewanya,Najaf, Karbala,Babel, Baghdad,Alanbar,Kut,Ammara.	MoC
Provinces	ITPC/Furatphone	Nasriya, Samawa, Kut	MoC
Provinces	Fanous	Salah aldeen, Kirkuk, Mousal, Sulamanyia,Erbil,Duhok,Diyala	CMC
Provinces	Newroz Telecom	Dhouk, Erbil, Sulamanyia	MoC/KRG

1.6 Internet and Computing

The Internet in Iraq dates back to January 2000, when the government formed The State Company of Internet Services (SCIS). This company provided Internet access to a people who were almost completely isolated from the world by their country's lack of media and communications ability. Internet access did not actually become available to Iraqis citizens until 2001 and when the government finally made access generally available, it did so in an extremely limited fashion.

Iraqi citizens had to accept many restrictions and conditions in order to use the Internet. They had to have the financial means. Moreover, they had to complete and sign an Internet subscription application which stated: "the subscription applicant must report any hostile website seen on the Internet, even if it was seen by chance. The applicants must not copy or print any literature or photos that go against state policy or relate to the regime. Special inspector’s teams must be allowed to search the applicant's place of residence to examine any files saved on the applicant's personal computer." [The Arabic Networks for Human right information’s, 2004]

In universities and institutions with Internet centres, those in charge intercepted and carefully reviewed any e-mails sent to students before allowing them to be delivered. They were also responsible for reading e-mails students intend to send before they were sent. This process, which occurred in addition to a similar censorship process in a central governmental department, added to the delay in message arrival. [The Arabic Networks for Human right information’s, 2004].

1.7 Telecom Infrastructure

The Iraqi fibre network was destroyed during the two gulf wars also the fibre network installed pre 2003 used out-dated technology. Original fibre had limited capacity and was not planned to meet the high demand for data required by the internet, private telecoms networks (Mobile, WLL & Wi-Fi) also the digital video broadcast services. Degraded performance due to continuous repairs with limited quality control, availability and reliability.

Within telecom infrastructure, Iraq has faced the following challenges until 2009:

a) International connectivity has been limited and at a high cost due to few operating international gateways depending on satellite and VSAT not fibre.
b) Quality of international calls has been low.
c) New development of microwave backbone network but still not operational.

d) Development of the fibre optic network with high levels of redundancy on it is final stages.

2. The need to operate international gateways in order to provide high quality connectivity to neighbouring countries and to international lines.

3. Building a landing station in the south of Iraq to linking Iraq to the Gulf and the world i.e. Iraq first submarine cable (Figure 1.1).

Figure 1.1: Iraq falcon submarine

1.8 Iraq mobile and ICT sector

Three operators share the market but Zain of Kuwait's subsidiary Zain Iraq has much the largest market share, with well over 50% of the market. Asiacell, which has Qtel of Qatar as a major shareholder, has just over 35% of the market. The third and smallest operator, Korek, which originated in the Kurdish part of Iraq and started to extend its reach to the main Iraqi city after Orange become one of the main share holders in 2011 has reached 10% of the Market.

Several Wireless Local Loop licenses have been awarded and operators have launched services using CDMA networks but they have not yet made much impact.

Inevitably these factors have led to very low levels of Internet subscribers. There are no reliable statistics for the numbers of Internet users but they are likely to be over a million. Most users access the Internet at Internet cafes with satellite connections that is very expensive and have limited bandwidth. With better backbone infrastructure mobile Internet services could probably be successful but 3G/HSPA services are not available yet.

There are many Challenges to Iraqi ICT, because the ravages of two wars and high military spending have damaged the infrastructure and diverted much investment from the civilian economy. The security situation and sabotage have reduced the return on reconstruction spending, delayed benefits, deterred investment and contributed strongly to the loss of many of Iraq's best and brightest people.
By clearly identifying the constraints on ICT progress, (many of which are constraining more than just ICT) policy, organisational and investment decisions can be better informed, and the great potential of the Iraqi economy can be realised more quickly to benefit the Iraqi public.

a. Human Capital

The loss of skilled personnel, often called the "brain drain" which occurred in Iraq, naturally has a greater effect where pay differentials are highest and where foreign demand is highest. The security challenges in Iraq coincided with a dramatic growth in Regional ICT spending and a period particularly active for starting new ICT projects – thus creating a sudden increase in demand and pay for Arabic speaking ICT workers in nearby countries. Significantly changing the culture and the underlying model of the workplace is a major undertaking in a stable environment, but the many concurrent challenges Iraqis have borne have made this transition historically wrenching.

b. Security

Despite the continued risk, there is a clearly improving trend, supported by continued improvements in the size and effectiveness of the Iraqi Security Forces and the declining support for anti-Iraqi forces. With enough time and money, any priority in Iraq can proceed, and World-Class talent can be brought to bear on it. As the situation improves and the risk premium declines, we can anticipate a growing stream of talent and capability for not only the same cost, but increasingly self-financed with Foreign Direct Investment and profits from an expanding economy in a self-reinforcing virtuous cycle.

c. Policy

Establishing new policy and processes throughout the Government and economy is still far from complete. The revolutionary change to the basic economic and governance model, adapting to new laws, new technology, international trade regimes and business practices; naturally strains the ability to reach consensus of opinion.

Delays in finalising policies, however understandable, inject uncertainty into investment decisions, contributing in turn to higher risk premiums and hesitation by investors. Beyond the effect of marginally higher cost, in certain instances the lack of finalised policy has prevented action. Policy decisions, as they are published, will contribute to coordinating efforts, by providing authoritative direction and clarifying how to resolve disputes.

d. Services

Simply put, the private sector has been hugely successful in improving telecommunications service to the Iraqi public, while State-Owned Enterprises have not. Commercially provided satellite television, voice and data services have blossomed. Cell phone service has exploded from basically non-existent in 2002 to approximately 24 million customers today. Internet availability is informally estimated to be in the millions through entrepreneurial small business providers, and the rollout of Wireless Local Loop services will improve availability and quality of service significantly.

e. Infrastructure

The long distance communications capability in Iraq since 2003 has been characterised by a heavy dependence on expensive satellite links for long distance or international connectivity. The existing terrestrial fiber optic and microwave networks have been the monopoly of a State-owned Enterprise, which has experienced a variety of challenges, such as extensive wartime damage, extensive collateral damage from roadside IEDs (Improvised Explosive Device), aged fiber, security constraints on repair, supply chain disruptions (such as parts or fuel); and a shortfall or complete lack of technical or sustainment support, sustainment training, and network management.

Another factor which is significantly and unnecessarily driving up costs and seriously limiting availability, is the shortage of cross-border agreements and functioning gateways with neighbouring countries and international undersea cable operators. Most notable is Turkey, which is Iraq's doorway to the huge European market. Additional revenue from communications to share with Turkey is a positive element, which could help to strengthen ties.

Despite inevitable problems, the telecoms sector is one of the big success stories of post-war Iraq. With a more settled security situation and better regulation and a liberalised market, the much-needed investment and development will surely follow.

1.9 Research Aim and Objectives

The aim of this research is to investigate the real reasons for "bad quality of services caused by interferences." (GSM operators)

The objectives of the research are as follows:

- To investigate the performance of GSM/CDMA wireless services in Iraq.
- To identify the reasons for detritions of QoS.
- Analysis of all GSM operators.
- Analysis of ITPC as the main CDMA operator and Nowros telecom in KRG.
- Recommendations for planning and optimisations.

The research analyses the existing wireless communication technology in Iraq and identifies the performance, focusing on the reasons for drop off of the quality of services.

1.10 Chapter outline of the thesis

The thesis is divided into seven chapters. The structure of the dissertation with a brief description of each chapter is given bellow:

Chapter 1 – Introduction: Provides the purpose and scope of this thesis and includes the background details, research aim and objectives.

Chapter 2: Examines the wireless communication technologies used in Iraq, in detail including GSM, WLL, WBBN, WiMaX, SCIS.

Chapter 3 – Studies the planning and development of the telecoms sector in Iraq

Chapter 4 – Discuses the wireless measurement plan and optimisation tools.

Chapter 5 – Discusses and analyses CDMA performance measurements and Qo

Chapter 6 – Discusses and analyses GSM performance measurements and QoS

Chapter 7 - A conclusion and further works of the research will be provided.

References: A list of references used in the dissertation.

Appendices: The research instruments, statistical analysis and background details of the thesis.

1.11 Summary

In 2011, Iraq's telecoms sector seemed to have everything going for it: a population of 31.2 million people hungry for the latest communication technology, improved security, and a healthy stable of public and private telecom operators competing to offer mobile, fixed voice and data services and overseeing it all by CMC as an independent Telecommunication regulator.

The main story of telecommunications in Iraq continues to be mobile. Before the Iraq war of 2003 mobile telecoms did not exist in most of Iraq outside the Kurdish areas. In the seven years since the launch of services in 2004, subscriber numbers have exploded to reach penetration levels much higher than in neighbouring Syria or in Lebanon, at nearly 70%. However, there remains room for expansion and annual growth levels are high at over 10% per year.

Part of the reason for the booming mobile sector is the lack of any significant fixed-line market. Fixed-line penetration levels are less than 6%. There is also a great lack of fibre-optic backbone infrastructure, both nationally and for international connections and the submarine cables still not on operations by mid 2012.

Thus, key to the future success of Iraq’s Communications needs is the continued deployment of Wireless Communications technologies and the employment of methods to improve its quality of service and manage the frequencies it requires more efficiently. This thesis will determine the actual reasons behind any deterioration of services through measurement and analysis and derive recommendations that suggest the best approach for deploying the Wireless communication technologies, which will be presented to the Iraqi Government, CMC and the wireless service providers.

Chapter Two

2.0 Wireless Communication Technologies Used in Iraq

2.1 Introduction

Wireless and broadband technologies are changing the way we behave, communicate and interact. Today's consumers want to be able to access their favourite applications, services and content anywhere and anytime using a wide range of devices. This desire for innovative devices and rich experiences is increasing data traffic and triggering a mobile data explosion.

Mobile phone penetration is growing rapidly, particularly in underdeveloped countries. Globally, the number of mobile phones supersedes the number of fixed/wired phones in 2003. This is also the case in many individual countries among these countries are Chad, Honduras, Indonesia, Jordan, Mexico, Mongolia, Nigeria, Philippines, Saudi Arabia and South Africa [Umar, 2004].

Telecom carriers are also increasingly using wireless technologies to address the "last mile" problem. This is especially popular in developing countries. For example inhabitants of remote villages in India have been connected to the internet through wireless local loops (WLLs). The WLLs based on fixed wireless technology connecting subscriber sites (Homes, Offices) to a local carrier office through microwave. WLLs are an attractive alternative to the wired networks in the last miles where the subscribers can be connected through wires due to terrain or hazardous situations [Umar, 2004].

Current research confirms the explosion concept. The New York Times says that iPhone users consume ten times more bandwidth than other Smartphone users. Bell Labs Analysis suggests that shifting all current video content to the Internet would increase Web traffic by a factor of 30.
Pyramid Research and Light Reading predict that annual worldwide voice and data revenues will grow at rates of 2.5% and 12.8% between now and 2013—and that data traffic will grow at 131% over the same period.
Iraq mobile phone penetration grows rapidly in the GSM and CDMA and part of the reason for this growth of the wireless communication sector in Iraq is the lack of any significant fixed-line market.

“Iraq's performance was excellent in the cellular competition intensity index, ranking first with a score as high as 91.0% and dethroning Jordan. There are five working operators in the country, three of which operate a national mobile license, while the remaining two are regional operators operating in the Kurdistan region. While Iraq’s largest operator (Zain) has a substantial market share of more than 50%, Iraq’s score benefited from the availability of corporate offers, operational ILD (International Long Distance) competition and 3G services.” Mr. Andrawes Snobar, Arab Advisors’ Research Manager wrote in the report. [Arab Advisors Group’s, 2009].

The telecoms sector in Iraq is one of the big success stories of post Iraq wars era i.e. after 2003 and two Gulf Wars.

2.2 GSM (Global System Mobile)

Although Iraq cell phone coverage can reach 90% of the population still the penetration is about 70%. Growth has been explosive in recent years. There are also no roaming agreements among companies, and there are not likely to be any time soon.
Reaching the last 10% of the population will be hard but there are means to extend cellular service to rural areas faster that need to be pursued, including possible incentives to the private sector.

The largest private mobile companies (Zain and Asia cell) provide GSM phones, while the government’s ITPC offers CDMA service as well other operators, besides Zain, Asia cell and Korek which is the third private cell phone companies with limited subscribers and coverage.

Zain claims to have more than 12million active customers, the Asia cell with about 9 million and Korek around 4.0 million mainly in North of Iraq i.e. Kurdistan Region (Figure 2.1)

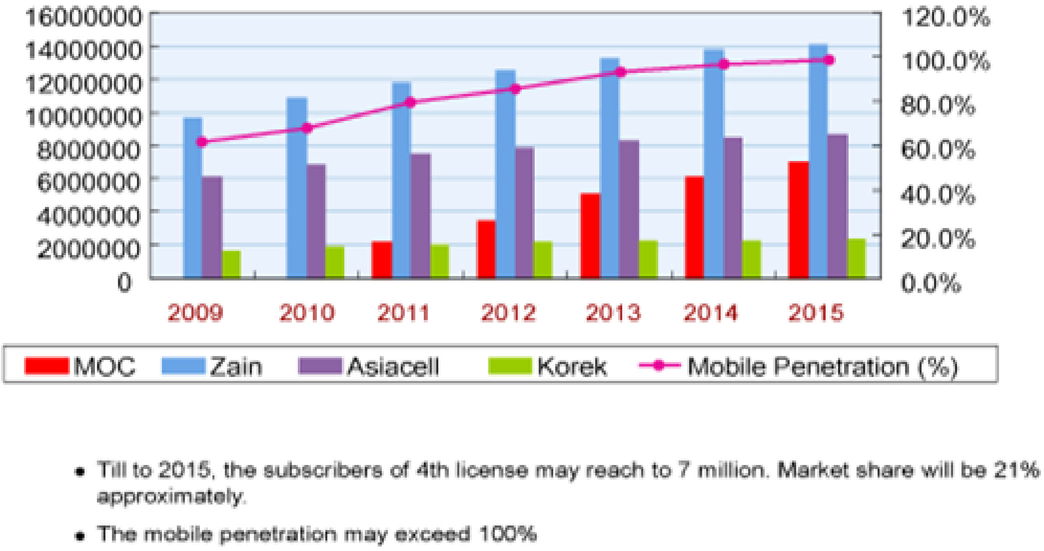


Figure 2.1: Iraq mobile telecom potential [Malak, 2012]

The operator's lack of innovation with regards to different plans and tariffs with peak hour calculations is the key to getting customers and ensuring their retention .For example the operators should provide different service levels on the bandwidth usage i.e. platinum, gold and silver customer levels depending on your surfing habits and how long you can surf.

This is still important factor the reliability in the connection to encourage customers to shift to GSM operators in their internet connection; internet users are type of customers that are very sensitive to speed and reliability provided by providers.

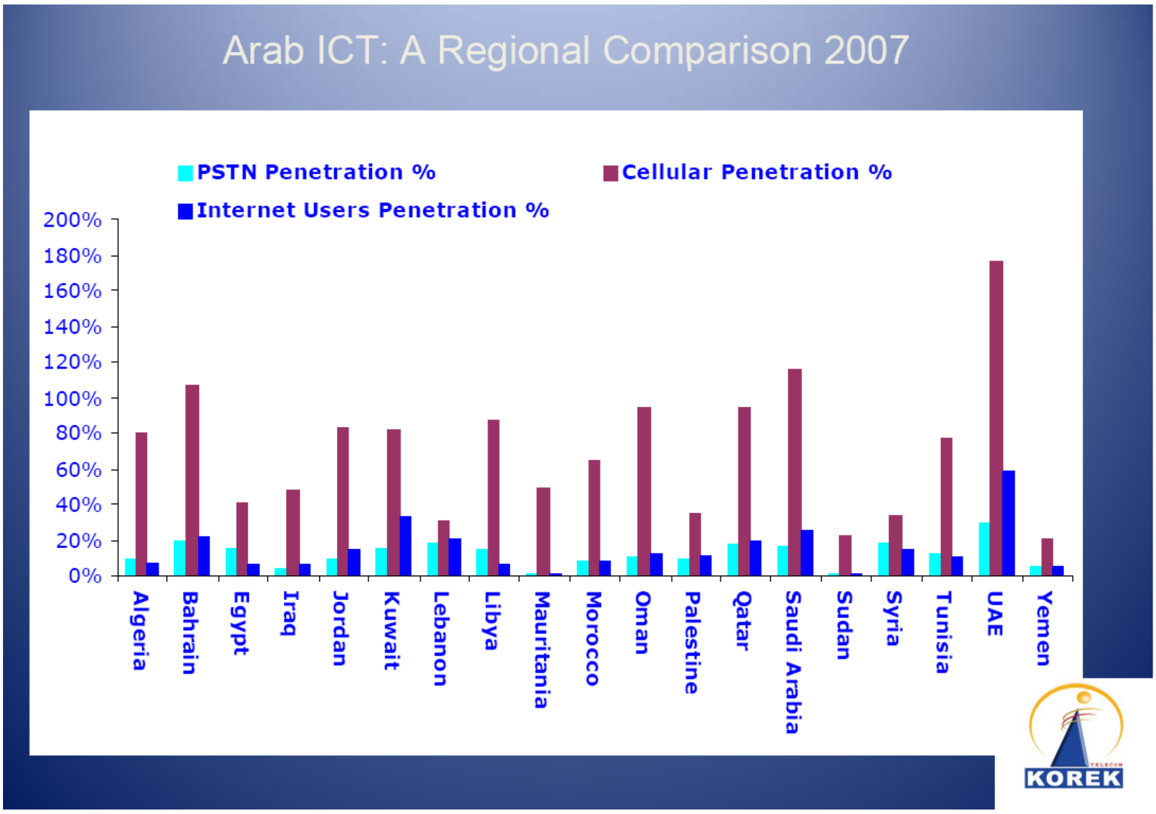


Figure 2.2: Middle East Comparison

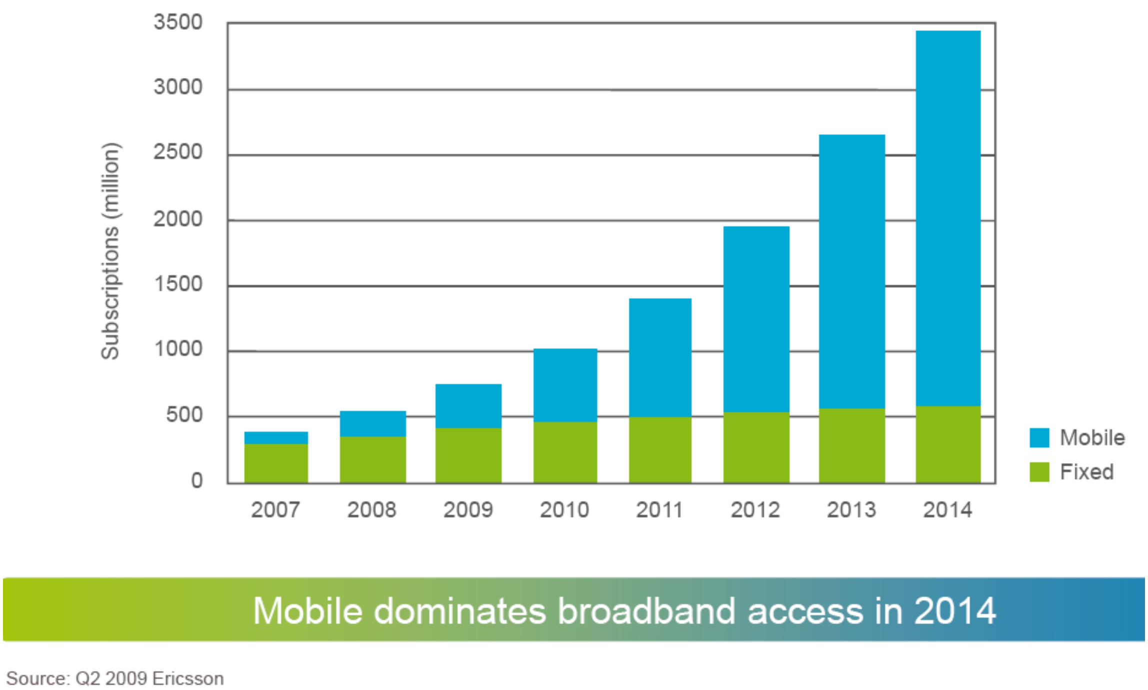


Figure 2.3: Middle East Broadband Access

In 2007, the cellular penetration percentage in Iraq is greater than 6 Arab regions shown in the comparison in figure 2.2. However, PSTN penetration percentage and internet user percentage is significantly weaker. The Middle East broadband access had dramatically improved and developed since 2007, with mobile significantly dominates fixed broadband access in 2010 and continues to expand until 2014 (figure 2.3)

Korek Establish as company in August 2000 in the Kurdish Region and launch operation in February 2001. They have awarded 10 years license to 2015 in KRG.
They have bid for National license in August 2007 and awarded the license for 20 years with license fee 1250 million dollar as the 3rd GSM operator.
Korek started mobilising rollout teams in cooperation with local companies in the central and southern regions of Iraq. Collocation of radio stations with other wireless providers. Inter connection through Satellite links as an interim solution for backbone.

Wireless technologies is playing crucial role providing connectivity in rural, remote and far areas .Iraq ranked first for the most competitive mobile markets in the Arab world [Hameed, 2009].

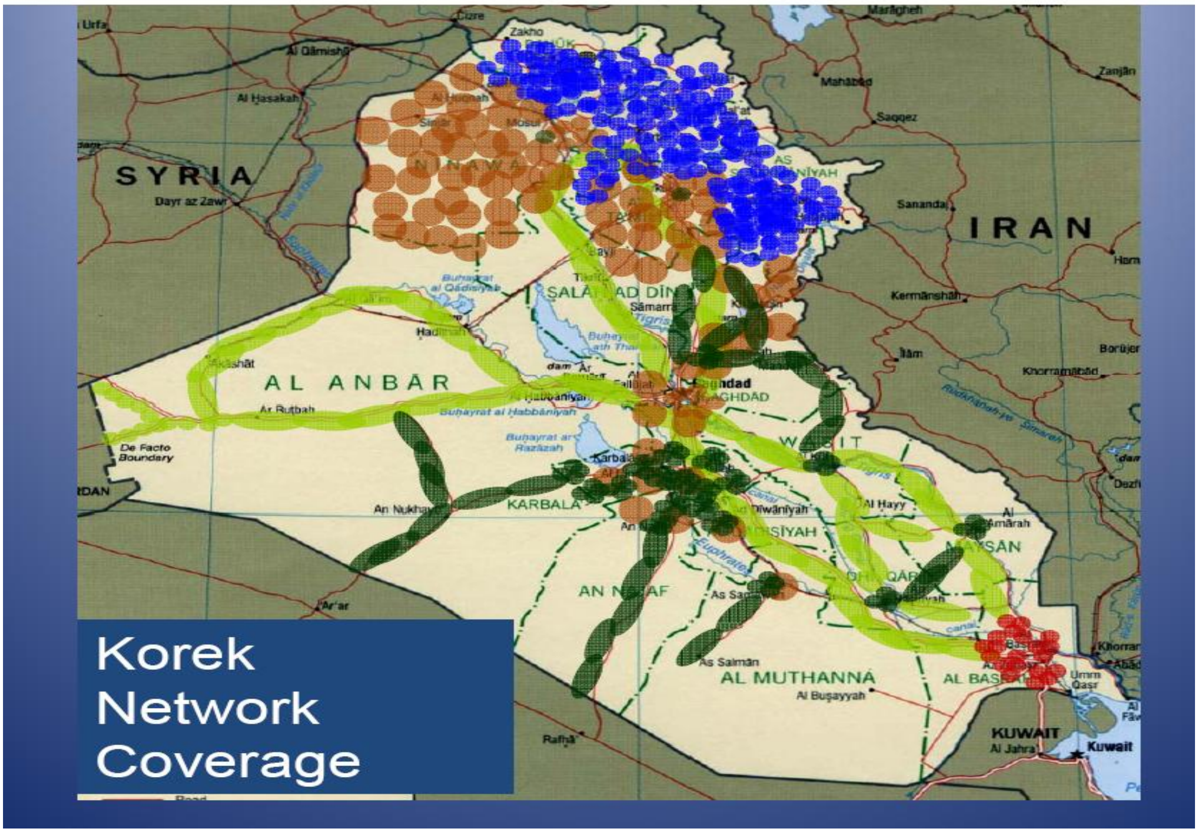


Figure 2.4: Korek Network Coverage

Korek coverage starts mainly in the Kurdistan region and has moved to Baghdad and Basra as shown in figure 2.4, but more expansion is needed to cover whole of Iraq.

AsiaCell the second Largest GSM operator in Iraq started operation in the North of Iraq since 1999. Over the last few years since 2007 when they awarded the national license, Asiacell was the first telecommunications venture in Iraq. Today, it is one of three GSM National operators providing coverage to the Iraqi nation in its entirety and catering to an impressive client base of over 9 million. Asiacell claims to be the biggest in its coverage area.

Asiacell's products and solutions are made for the people, meeting the needs of the people and offered at prices suitable for the people. The aim is to quickly bring Iraq into the 21st century, and to allow its communications industry to become one of the fastest-growing industries in the world. Through our rigorous research and development efforts, our continuously expanding partnerships and the trust we have inspired in the Iraqi public, this ideal is quickly becoming part of our reality” [Faruk, 2009].

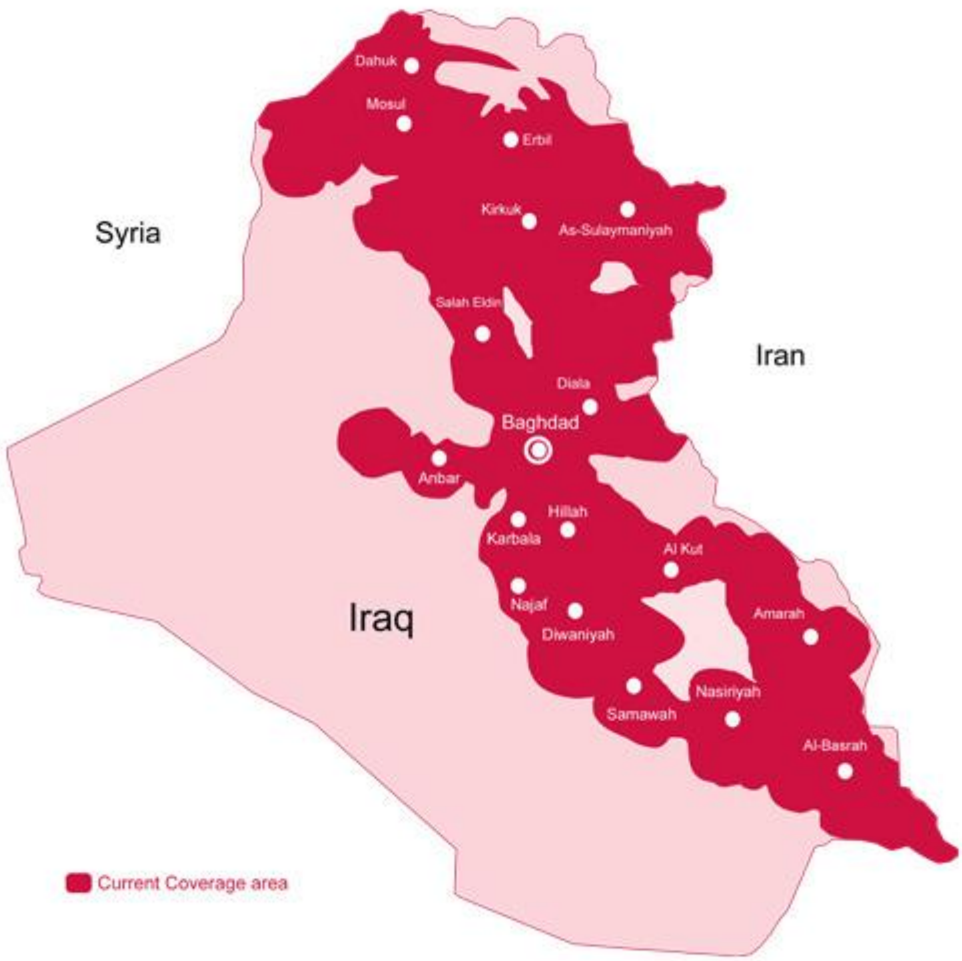


Figure 2.5: Asiacell network coverage

Asiacell's network coverage is over the whole of Iraq in the major city but still have to expand across Iraq in the west and south regions as shown in figure 2.6

Zain (formerly MTC) is the pioneer of mobile telecommunications in the Middle East and now a major player on the African continent. They are a leading mobile and data services operator with a commercial footprint in 24 Middle Eastern and African countries with a workforce of over 15,000 providing a comprehensive range of mobile voice and data services to over 69.5 million active individual and business customers [Zein, 2009]
In the Middle East Zein operate in many countries like Bahrain, Jordan, Kuwait, Saudi Arabia and Sudan. Also in Africa, Zain (formerly known as Celtel) offers telecommunications services in Burkina Faso, Chad, Democratic Republic of the Congo, Republic of the Congo, Gabon, Ghana, Kenya, Madagascar, Malawi, Niger, Nigeria, Sierra Leone, Tanzania, Uganda and Zambia. Zein listed on the Kuwait Stock Exchange,

there are no restrictions on Zain shares as the company's capital is 100% free float and publicly traded. The largest shareholder is the Kuwait Investment Authority (24.6%).

Zain in Iraq first provided its services in 2003 as MTC Atheer and after the acquisition of Iraqna; both companies were re-branded to become Zain-Iraq in January 2008. Having the largest network in the country, Zain-Iraq currently prides itself to have nearly over 10 million customers who enjoy the securest and most affordable cellular services. Zain-Iraq has, ever since 2003, been providing a wide range of mobile telephony and various services like MMS, GPRS and recently Blackberry [Zein, 2009].

Mobitel is Iraq's newest mobile phone network. It was awarded a 3G mobile license by the Kurdistan Regional Government and has recently launched its services. Mobitel Iraq is the result of local and foreign investment that believes in the economic growth of Kurdistan region. MobiTel being the first 3G operator in Iraq and the region (see table 2.1).

Table 2.1: Current GSM Operators

Operator Name	**License Type**	**Subscribers**
Zein Iraq	National	12.5 Millions
Asia Cell	National	9.0 Millions
Korek	National	4.0 Millions
MobiTel (3G)	Provinces (Dhouk, Erbil)	10000

2.3 WLL (Wireless Local Loop)

The CDMA technologies offer the capability of the broadband access. CMC/MOC introduce the technologies to Iraqi market and thought it was the right time to deploy in the Iraqi Telecom market. The CDMA operators are adopting EV-DO, Rev.0 or Rev.A.
ITPC adopted CDMA to lower the CAPEX/OPEX and offer the fixed wireless and contract with ZTE and Huawei to deliver the 3G CDMA 1X/EV-DO solution in Iraq i.e. Baghdad and Najaf.

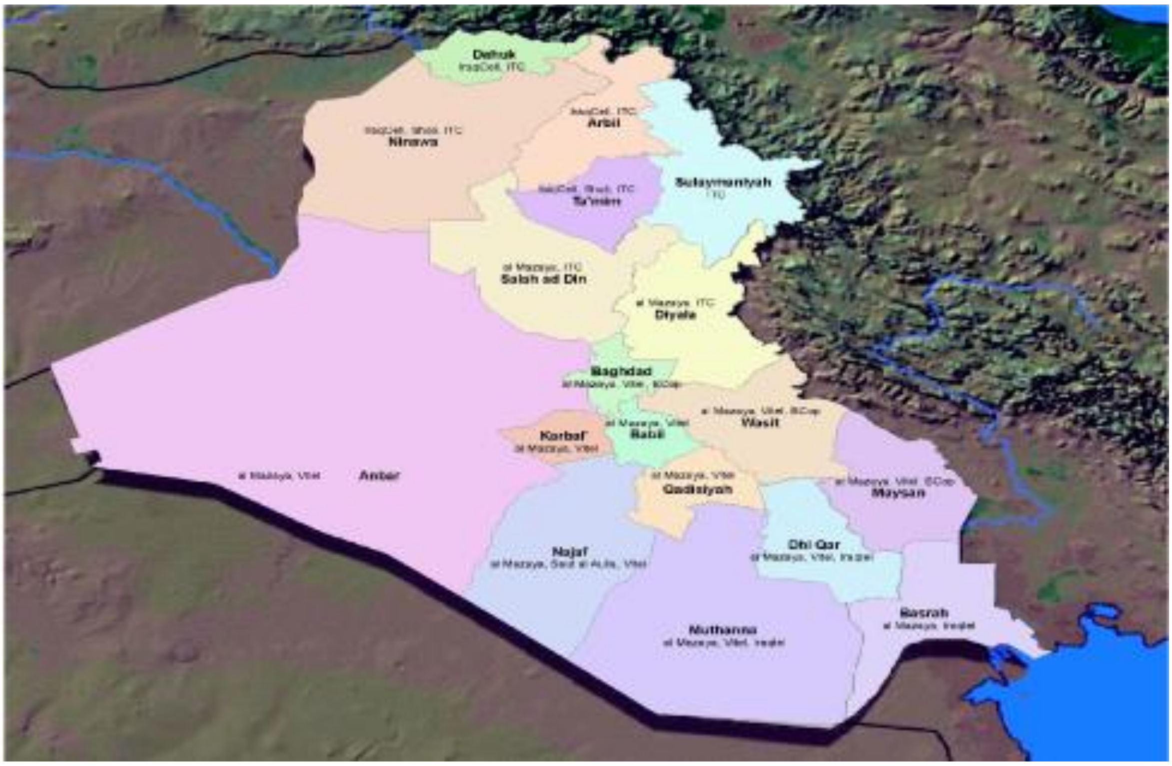


Figure 2.7: CDMA Licenses

Table 2.2: CDM Licenses

Province			ITPC						Provincial		
	Kalimat	Sukhtian	Al Mazaya	ITPC	IraqCell	Saut al Aulla	Shali	Vitel	Baghdad Cooperative	Iraqtel	ITC
Al Anbar	●	●	●					●			
Al Basrah	●	●	●							●	
Al Muthanna	●	●	●					●		●	
Al Qadisiyah	●	●	●					●			
An Najaf	●	●	●	●		●		●			
Arbil (Erbil, Irbil	●	●			●						●
As Sulaymaniyah	●	●									●
Al Tamin	●	●			●		●				●
Babil	●	●	●					●			
Baghdad	●	●	●	●				●	●		
Dahuk	●	●			●						●
Dhi Qar	●	●	●					●		●	
Diyala	●	●	●								●
Karbala	●	●	●					●			
Maysan (Missan	●	●	●					●	●		
Ninawa	●	●			●						●
Salah ad Din	●	●	●								●
Wasit (Wassit	●	●	●					●	●		

Table 2.3: Current CDMA Subscribers

Number of Subscribers	Operators Name
320000	Itasaluna
60000	Kalimat
32000	ITPC
340000	ITPC/Omnea
15100	ITPC/Furatphone
228000	Fanous
600000	Newroz Telecom

Kalimat Telecoms one of the main CDMA operators in Iraq who won the National WLL license in 2007 and they are on progress to spread their coverage to cover the major cities first. Present time Kirkuk and Baghdad.

Kalimat Telecom aims to enter every home, business, governmental and non-governmental institution in Iraq and deliver five million CDMA and WiMAX lines of service by 2011. The rollout of the Wireless Local Loop (WLL) network is designed to cover the entire Iraqi geographic spectrum. This will create one of the Middle East's largest CDMA wireless telecom network – a network that is scaled and engineered to support current and future communications technologies consisting of voice, VOIP, data transfer, and media volumes anticipated for the next 25 years. [Wilson, 2009]

In addition to providing voice telephony services for local, national and international calling, access to the Internet (including broadband access), Kalimat will also deploy WiMAX technology – which provides wireless data over long distances – in Iraq.

Kalimat Telecom Targets to gain about 5 million Residential and business subscribers in four years, which is almost 20% of the market. They estimate that about 70% of Kalimat's revenue will come Data and 30% Voice. 80% - is expected to be Residential Subscribers and the remaining from business Subscribers (see table 2.3).

Throughout the years Iraq has led most of the West Asian Middle East in the fields of technology, transportation and logistics. It has an extremely well educated and affluent society with strong family values. Given the rights tools and the correct training to use them Iraq has a potential to rival many Middle Eastern neighbours who have claimed to hold the lead in IT and Telecoms in the region. We are going to provide all set of communications services like Voice, Data EVDO Rev A, WiMAX but we will concentrate on the value added services like Mobile TV, Interactive Services etc [Wilson, 2009].

Itisaluna the second and largest operator in Iraq launched it's services in March 2008.Itisaluna expanded it's coverage to cover 8 provinces and plans to cover all Iraqi provinces by the end of 2013. Itisaluna's subscriber base has witnessed a remarkable increase of 44% in 2010.Since 2011 and the recent months they still suffering and only approaching 0.3 Million subscribers.

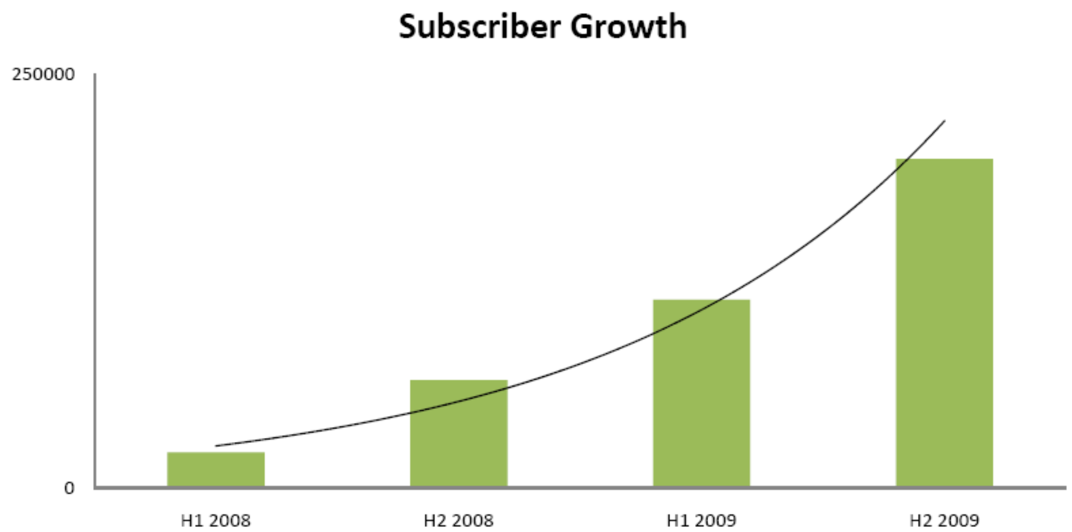


Figure 2.7: Itisaluna subscriber

Omnnea is one of few companies who work under ITPC WLL license and they have been working for the last four years. Omnnea extended its wireless network coverage to the province of Nasyrea north of Basra also covering Baghdad, Basra, Babel, Najaf, Karbala, Dewanea, Semawa and Nasyrea. Work is under way to complete its national network coverage in all of Iraq except) Karkuk, Mousel, Tikret) . They are providing wireless fixed and mobile voice, data, and internet services for its residential, business, corporate and government clients in Iraq. They have reached over 300000 subscribers by end 2011 (See table 2.3).

As a Wireless Local Loop (WLL) communications provider, Omnnea focuses its services in the fields in which it has developed its core competencies: Voice, Data and Internet

Telecommunications services. Within these parameters, Omnnea provides professional communication services are Fixed and mobile telephone services; Fixed and mobile Internet and Data (SMS) services; High-speed data; Point to Point (Leased Lines) data lines; Multi-line services; Facsimile line services; Roaming services with GSM networks; and Value added services, such as three way calling, call forwarding, IVR (Interactive Response, call forwarding, etc.) [Zawya, 2009].

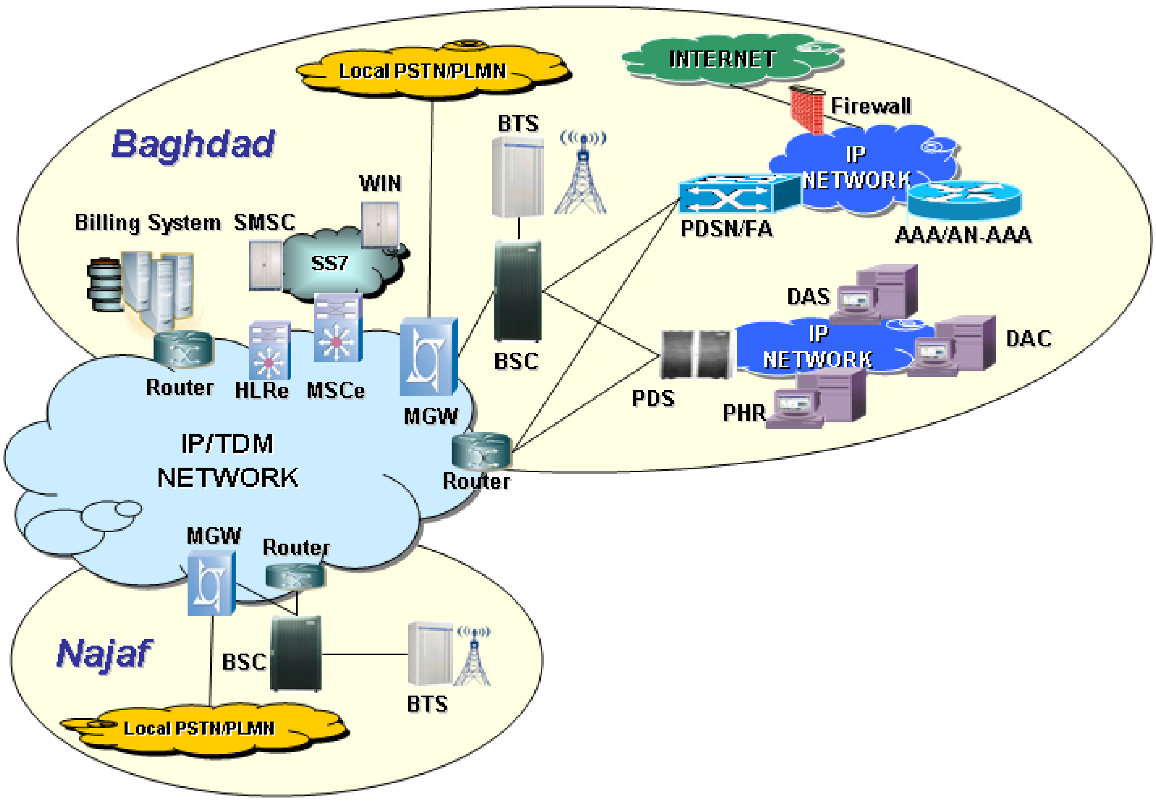


Figure 2.8:ITPC CDMA Overview

Newroz Telecom, Reber World the trade name for Newroz Telecoms was established on June 2009 in Dohuk-Kurdistan and it is one of the first company in Iraq and the only company in Northern Iraq region (Kurdistan), which provides local land line numbers in a VOIP (Voice Over Internet Protocol). Reber World is Newroz Telecom's trade name, which provided a local landline numbers and CDMA Reber handset [Reber, 2012].

Newroz Telecoms have three different frequency point at 450MHz, 7 frequency point at 800MHz also 3 frequency points at 1900MHz.currently they have around 600k users inside Kurdistan for Data and voice. They have different packages in the market are:
They have monthly package: 25,000 IQD, unlimited speed, with up to 7GB volume per

month.

Also offers hourly package: 750 IQD per hour "at the busy hour" and 250 IQD "at non busy hour”. Voice offer: 1000 IQD with 3000 min on net per month (See table 2.3).

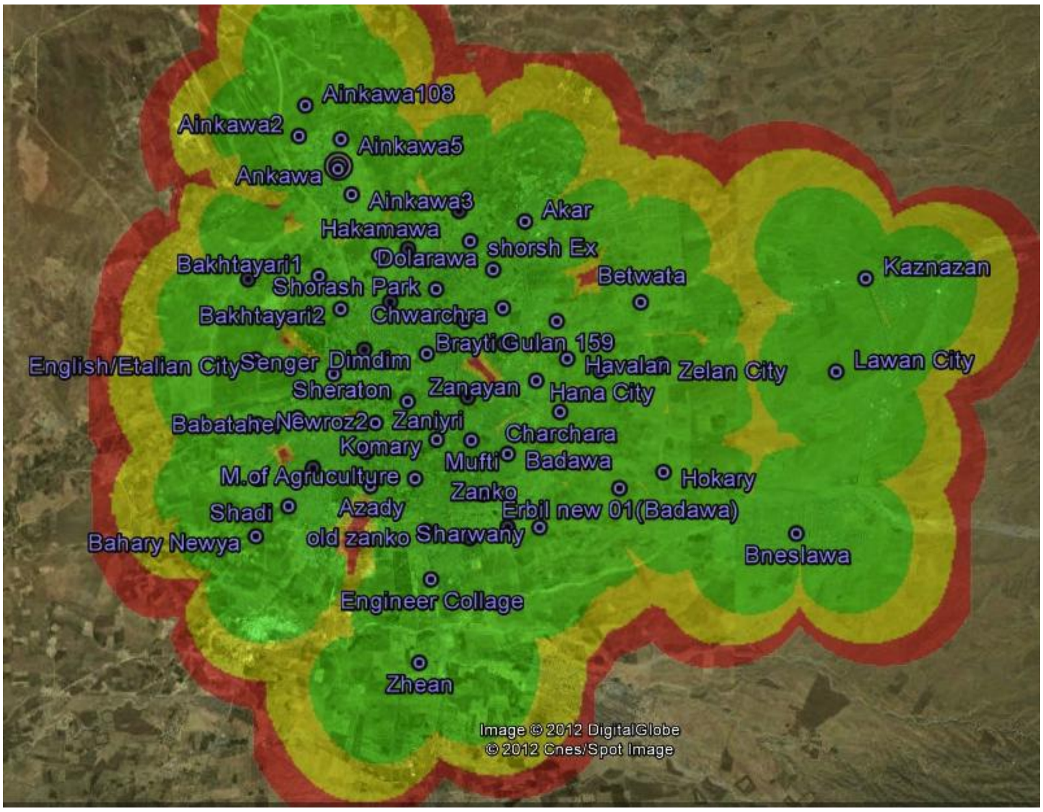


Figure 2.9: Newroz Telecoms CDMA coverage in Erbeel

Figure 2.10: Newroz Telecoms CDMA coverage in Dhouk

Fanous a sister company to GSM Asiacell which one of the main operators in Iraq. Fanoos' license from the National regulator enables to provide voice and broadband data services across the Northern Governorates of Iraq.

Fanoos is one of the market leader in CDMA and provision of voice services to homes and businesses in the northern region with approximately 300,000 customers. Recently introduced broadband data services (see table 2.3).

Fanoos WiMAX is a true broadband solution that provides connectivity on wireless technology. Fanoos WiMAX provides customers hassle-free and immediate access to high speed Internet.

Fanoos Telecom is a licensed telecommunications services operator to provide voice and data services to residential and business end users through utilisation of advanced CDMA 1X technology system and WiMAX. Fanouse work on 1900 MHz WLL also they have 11MHz on 3.5 GHz WiMAX.

They operate in Kirkuk, Mosul, Dohouk, Erbeel, Sulimanyia, Salah El Deen and Diyala

Furatphone Its second CDMA WLL operator works under ITPC License and provides telephone and internet services in three major cities Nasiriya, Kut and Muthana. With about 15 000 subscribers (See table 2.3).

2.4 WiMaX (Worldwide Interoperability of Microwave Access)

WiMax is a standards-based wireless technology that provides high-throughput broadband connections over long distances. An implementation of the IEEE 802.16 standard, WiMAX (short for Worldwide Interoperability of Microwave Access) provides metropolitan area network (MAN) connectivity at speeds of up to 75 Mbps per base station, with typical cell sizes of 2 to 10 kilo meters. This is enough bandwidth that a single base station can simultaneously support more than 60 businesses with T1/E1-type connectivity or hundreds of homes with Digital Subscriber Line (DSL)-type connectivity. The current IEEE 802.16-2004 (previously known as IEEE 802.16d) standard supports fixed access operation also WiMax Forum defined the portable and mobile operation standard (802.16e). This means that WiMAX is uniquely positioned to support applications requiring advanced Quality of Service, such as Internet telephony and streaming video [MEC Telematik, 2007].

According to existing allocation mechanisms, the frequencies allocated to each WiMax operator are far from meeting the requirements for large – scale cellular network .The WiMax forum expects globally uniform frequency spectrum in 2.5 GHz or 3.5 GHz band to be allocated for WiMax standard, but it is still unknown whether enough spectrums can be obtained.

The technology to support reliability for 2.5GHz has developed so quickly that there is a shift of mind to adopt 2.5GHz as it is widely not utilised till today and Iraq is a clean example.

The WiMax system was first introduced as broadband wireless system. In the physical layer, it uses such advanced technologies as Multiple – Input Multiple-Output (MIMO) , Orthogonal Frequency Division Multiple access (OFDMA) and adaptive modulation /encoding to improve its data transmission rate, in the MAC layer, it enlarges its system capacity and delivers QoS – guaranteed data transmission services by means of adaptive resource allocation. [MEC Telematik, 2007]

Table 2.4: Frequency allocations to WiMax as part of WLL licensed operators in Iraq

ITPC / MoC

Mobile TX (MHz)				Base TX (MHz)	Bandwidth
3409.750	3413.250	3416.750	3421.125	TDD	4 x 3.5 MHz

SUKHTIAN (National)

Mobile TX (MHz)				Base TX (MHz)	Bandwidth
3425.500	3429.000	3432.500	3436.000	TDD	4 x 3.5 MHz

KALIMAT (National)

Mobile TX (MHz)				Base TX (MHz)	Bandwidth
3441.250	3444.750	3448.250	3451.750	TDD	4 x 3.5 MHz

BAGHDAD COOPERATIVE (Baghdad, Wassitt, Messan))

Mobile TX (MHz)				Base TX (MHz)	Bandwidth
3457.000	3460.500	3464.000		TDD	3 x 3.5 MHz

IRAQTEL (Basra, Thi Qar, Muthanna)

Mobile TX (MHz)				Base TX (MHz)	Bandwidth
3457.000	3460.500	3464.000		TDD	3 x 3.5 MHz

ITC (Diayla, Kirkuk, Sulaymania, Erbil, Dahuk, Mosul, Salahaldin)

Mobile TX (MHz)				Base TX (MHz)	Bandwidth
3457.000	3460.500	3464.000		TDD	3 x 3.5 MHz

Notes: TDD: Time Division Duplex. Transmit and receive on the same channel.

Kalimat Telecom, Iraq's national telecom operator, has launched the first WiMAX network in Baghdad. Kalimat Telecom will use WiMAX radios from Redline Communications for fixed wireless communications. The $500 million project aims to provide broadband Internet services to 32.5 million Iraqi citizens. The network operator plans to secure an ambitious 60% of Iraqi subscribers over the next two years.

Kalimat Telecom is the privately-held Kuwait subsidiary of Kalimat Telecom BVI. The network operator provides fixed wireless local loop (WLL) telephony and data services. Less than one Millions Iraqi citizens have Internet access (3 % penetration). Iraq's Communication and Media Commission awarded Kalimat Telecom a 10-year wireless license in September 2006.

"We are proud to announce the launch and make it happen despite the prevailing situation," said Wilson Varghese, Kalimat Telecom CEO and President. "We are targeting customers like large commercial facilities, residential areas and government institutions. As you know many investors do not want to go to Iraq, but we managed to invest … and we are slowly getting there."

Several new services are anticipated for the small and mid-sized enterprise (SME) sector and large enterprise organisations. "The WiMAX service will allow provisions of up to about 21 Mbps per sector in the four sector base stations that Kalimat uses," says Dr Nasi Abachi, CTO, Kalimat Telecom. Multiple tiers of service are therefore possible, varying in speed, to a relatively large number of users.

In Kurdistan region there are three WiMax operators see table 2.5.**Nawand Net** with about 700 subscribers deliver fast and reliable wireless broadband internet connection to end-users and companies. Benefit from high speed Internet access and wireless broadband services with speed up to 25 times faster than regular dial-up.
Nawand Net offers connection speeds starting from 256Kbps to 512Kbps, Wireless broadband Internet access offers a service that is: Always on, simple, fast, reliable, secure, affordable and portable. Browse the Internet; download large files; exchange emails; and chat endlessly with friends and relative all for FIXED monthly subscription fee. [Nawand, 2013]

Netlayers Telecom, a major Iraqi telecoms operator established in 2008, just launched a mobile wireless broadband network in Kurdistan. Their brand name called WEGO, which is true mobile wide area broadband service based on WiMAX technology. 7Layers Net offers individual, residential, and corporate users high speed by simply connecting one of Wegoterminals to your notebook or Desktop PC. 7 layers telecoms use Chinese equipment vendor Huawei Technology for their complete WiMax solution to provide wireless broadband services for different levels i.e. students, SMEs, and large corporations at download speeds of up to 18Mbps. They have different plans as follows:

7Netlayers was established in 2008 by a group of Iraq/Kurdish and Lebanese investors whose vision was to deliver cutting edge technology and state-of-the-art interconnectivity solutions to the corporate industry and to the growing needs of consumers in Iraq-Kurdistan. Even though 7Netlayers obtained its license in 2007, it was not until May 2009 that it started its operations and launched commercial services in January 2010 using latest WiMAX 208.16e mobile technology to deliver the Mobile Broadband Wireless Access [Netlayer, 2012].

Table 2.5: Current WiMax Operator

License Type	**Operators Name**	**Provinces**	**Issued By**
National	Kalimat	Baghdad	CMC
Provinces	SCIS	Baghdad	CMC
	Newroz Telecom	Erbil, Duhok	MoC/KRG
	Nawand Net	Erbil, Duhok	MoC/KRG
	7Layer Net	Erbil, Duhok	MoC/KRG

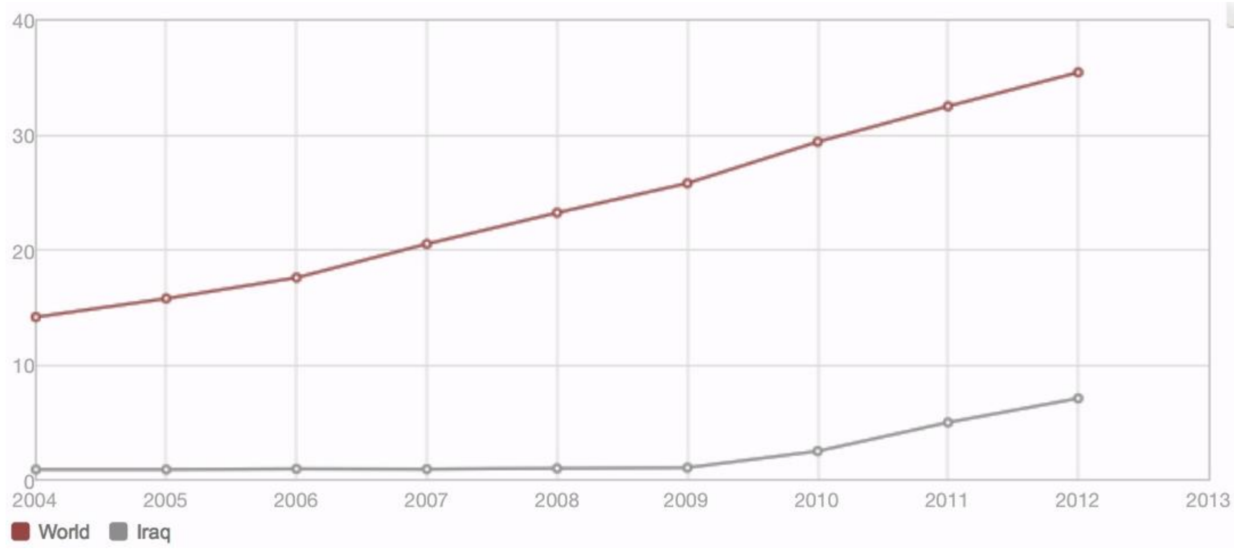


Figure 2.11: Iraq internet users (Per 100 people) Source: The world bank, 2013

One of the most important projects implemented by Central Bank using WiMax is the Iraqi Inter-Banking Network (IIBN) is a closed private network primarily designed for inter-banking communication with possible secure connectivity to Internet.

Iraqi Inter-Banking Network (IIBN) topology is formed by two main sites of Central Bank of Iraq (CBI-1 and CBI-2), participant banks sites in Baghdad and outside Baghdad and distribution sites in Baghdad. Central Bank sites and distribution sites are interconnected with MW links. Participant banks sites in Baghdad are connected to distribution sites using WiMAX. Participant banks sites outside Baghdad are connected to Central Bank sites with VSAT.

IIBN is designed to connect central sites, distribution sites and participant banks sites together. This is the only WiMAX technology used in Iraq with the microwave as a backbone connectivity. The central sites (CBI-1 and CBI-2) and distribution sites (Rafidain Bank, Al Alwiyah and Al Mamoon). These sites are connected to a ring by microwave radios. Ring topology ensures redundancy of connections between sites. Connecting the distribution sites to participant banks sites with redundant WiMAX connections. Each participant bank is connected to two independent WiMAX Base Stations, it means to two independent distribution sites, to ensure service quality and backup, shown in figure 2.4.

CBI-1 and CBI-2 sites together with distribution sites form a ring. Sites in this ring are connected using microwave link of capacity 155 Mbps. CBI sites are connected together by private redundant microwave link independently on the main ring. Because of CBI-1 and CBI-2 buildings height and line of site requirements for microwave link, retranslation over telecommunication tower on Al Mamoon ITPC site and telecommunication tower on Al Alwiyah ITPC site used.

IIBN – Network Overview

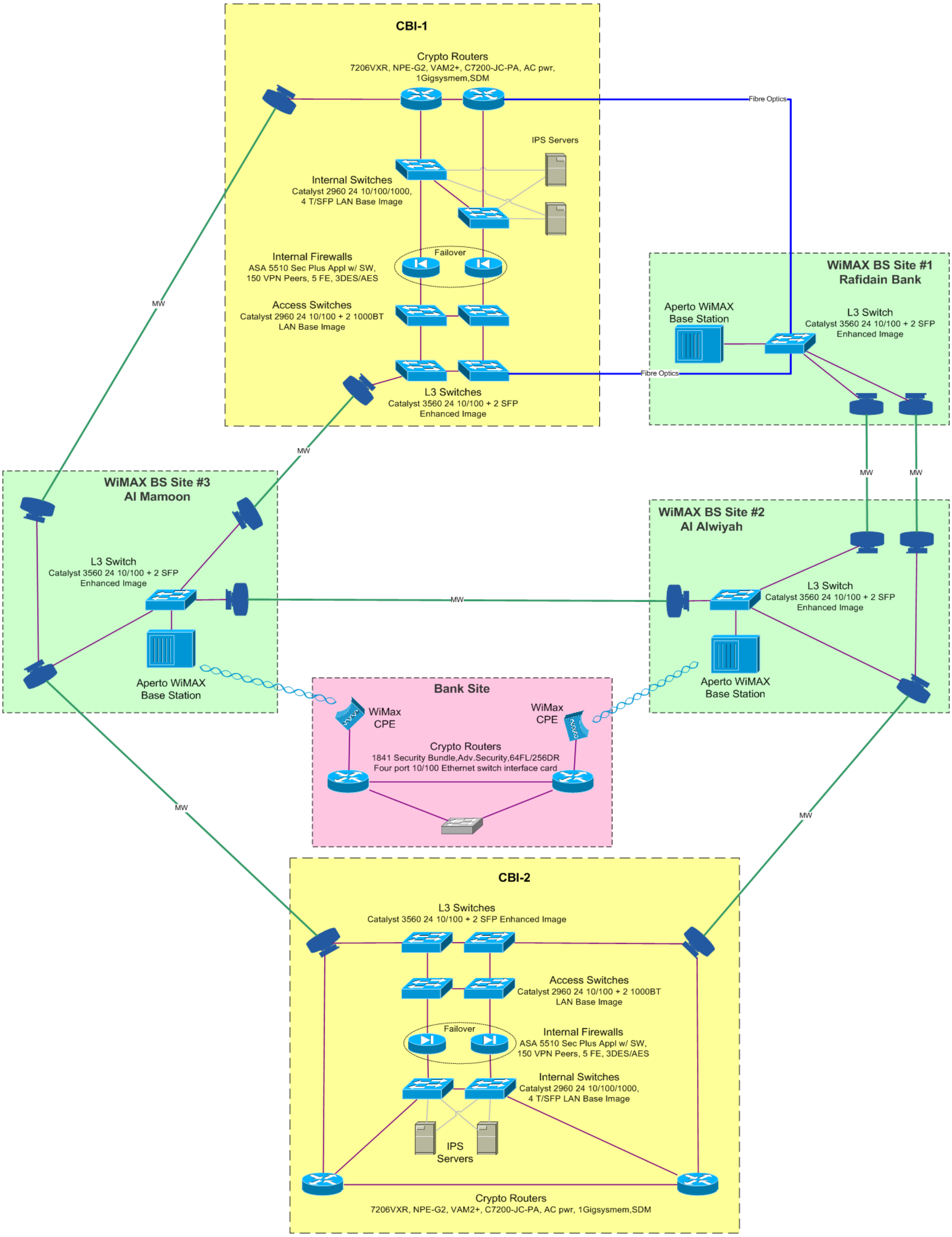


Figure 2.12: IIBN - Network overview

2.5 State Company of Internet Services (SCIS)

SCIS decided to use WBBN as backhaul for WiMax i.e. The currently available WiMax base station equipment is designed to interface to the backhaul network using 10/100/1000 Base-T Ethernet (varies by vendor). This corresponds well to the available connection types within the WBBN, as the WBBN is an ATM-based IP network. The three basic interconnection scenarios previously identified and illustrated are expanded up here in terms of the hardware components, estimated costs, technical requirements and limitations of each scenario.

The traffic in the WBBN is backhauled to the GoIC/IGB over dedicated STM-1 (155 Mbps) microwave links. In a similar manner, WiMax traffic can be backhauled to either an existing WBBN Node or the GoIC/IGB via a new microwave link. The traffic would then be terminated or combined with other WiMax traffic arriving via the WBBN. In the case of using the GoIC/IGB as the near end of a PTP microwave link, this will provide two advantages to the WiMax operator. First, by returning the traffic directly to the GoIC/IGB, substantially higher capacity backhaul is possible because the traffic does not have to ride on the WBBN backhaul links; the full STM-1capacity could then be utilised. Second, the WiMax operator can tailor the microwave capacity and frequency to suit the requirement of the WiMax base station, potentially realising longer paths, unlicensed frequencies, or lower hardware costs.

Figure 2.15 below illustrates the hardware required for this concept. Currently two WBBN sites, Ministry of Trade and Central Bank of Iraq make use of this configuration.

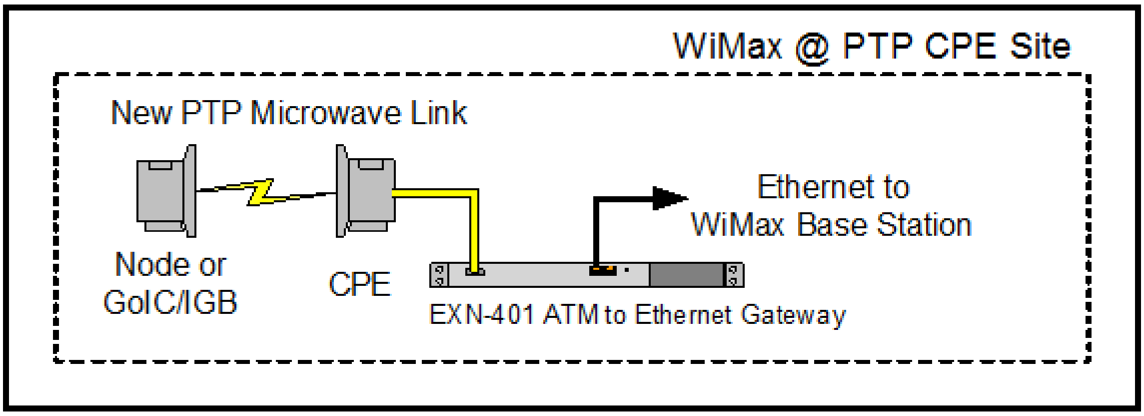


Figure 2.13: WiMax Interconnect using PTP Microwave

The cost of this is high primarily due to the cost of the dedicated microwave hardware. The unit prices below assume a protected 23 GHz STM-1 link as used in the WBBN backhaul. The use of different frequencies, bandwidth and technology could dramatically affect the cost of such a link.

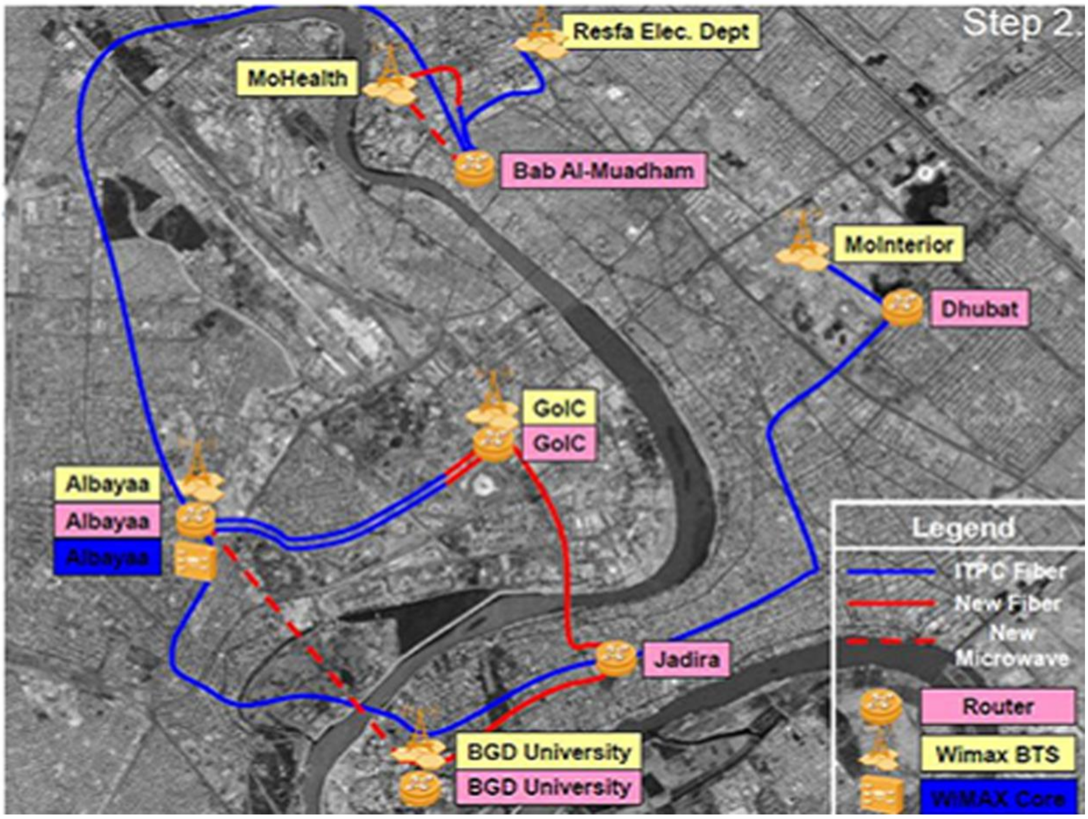


Figure 2.14: WBBN main links and nodes

One of the WBBN Node sites can also be used as the near end of the new PTP microwave link if the WiMax site is too far from the GoIC/IGB for a reliable direct microwave link or clear line-of-sight can not be achieved. However, in this case, much of the advantage of bringing the WiMax traffic directly to the GoIC/IGB is lost since the WiMax traffic would be allocated only a portion of the shared WBBN backhaul capacity. Also, in addition to the above hardware, an additional ET-155SC card would be needed at the node to bring the WiMax traffic into the WBB network raising the cost even further.

The existing WBBN system is ideally suited to support the rollout of a WiMax network in Baghdad. The primary advantage is that the WBB network is able to support WiMax Base Stations at a variety of geographic locations, and can be ready to backhaul WiMax traffic as quickly as the interface hardware is installed.

2.6 Summary

Iraq mainly relies on fixed line with 3 mobile GSM operators (Zain, AsiaCell, Korek), and as well 3 main national and 2 provinces CDMA operator. Furthermore, the limited WiMAX used by central bank of Iraq. The CDMA is mainly use as a fixed broadband to replace the lacking of fixed landlines.

The GSM market have over 25 million subscriber, which is over 70% of the population. This shows the growth is mainly in the GSM market compared to CDMA, which has less than 1.5 million, which is largely used for the internet.

WiMAX at the moment is only used in governmental banks but the technology should be widely expanded and used for commercial and home users to give more and better quality of internet service for users in Iraq.

Chapter Three

3.0 Planning and Developments of GSM/CDMA backbone infrastructure

3.1 Introduction

Telecommunication plays a vital role in rebuilding Iraq, providing social stability, improved quality of life while contributing to economic growth through new telecommunications revenue. Since the war, Iraq has been among the Middle East's weakest telecom markets, with only 3 lines per 100 population, comparable to the world's poorest developing economies in Africa, Latin America, and Asia. The average for the Middle East region is 13 lines per 100 populations, and Iraq's neighbours all have stronger telecom networks: Iran has 19 lines per 100,
Saudi Arabia has 14, Syria has 12, and Turkey has 28. This puts Iraq in the position of disadvantage compared with other developing economies. [Monetti and McMenamin, 2009].

Information and Communication Technologies are powerful forces in the world today, which affect the entire economy and all of the Ministries. These tools can dramatically improve the lives of virtually all Iraqis, and, can make a dramatic improvement in the ability of the Government to satisfy the needs of its people. These technologies are transforming the world today, and are advancing like a speeding train. Strong ICT is essential to compete in today's Global economy and continue to grow in relative importance. However it requires long lead times, significant investment in a long term infrastructure and a large number of skilled people. Iraq needs these capabilities to rise to eminence among the countries of the world and to provide the highest standard of living for the Iraqi people.

Iraq faces the same ICT challenges as the rest of the world, as well as those unique to the Iraqi situation. Staying up to date with rapidly changing technology is a global challenge, which was more difficult in Iraq during the period of sanctions. Maintaining a supply of highly skilled labour is a global challenge, made even more difficult in Iraq by a serious brain drain driven by security concerns and wide gaps in salary. Finding the optimal balance between Government and the private sector roles is a global challenge made more

challenging by the legacy effects of an extreme dictatorship which operated so far from the most effective best practices.
The private sector has been spectacularly successful in delivering communication service to Iraqis – and has done so at no cost to the Government. Indeed, as private telecommunications companies provide more services to the people and economy, they provide more revenue to the Government. Able to adapt quickly, incentivised to perform and able to attract the best talent; the private sector has dramatically improved telecom sector performance in Iraq and around the world – both throughout the economy as well as in support of Government operation.

Since the war, Iraq has relied on wireless technology for a rapid increase in lines. Iraq Telecommunications & Post Company (ITPC) has a 100% market share serving 1.3 million subscribers. While encouraging, wireless services does not provide a means for emergency communications common in services nor does it provide high speed internet access services. Investments to enhance and expand ITPC's existing landline network are essential. It will create new jobs, and give the private sector opportunities, support local and international businesses with voice and high speed internet access as well as Multimedia services.

3.2 Submarine Cables

Submarine cable involves a process of laying physical core cable, which carries hundreds or thousands of fibre optic strands, on the bottom of the ocean floor. Submarine cable is a transmitter-receiver communication system, which connects to other cable systems or to land-based receiving stations.

Many third-world countries and isolated continents have benefited from the use of submarine cable. They once had to rely on land-based systems and satellite transmissions. No limits exist for the length of cable, which can be laid to link up other countries and remote islands. The application of submarine cable has positively increased the amount of bandwidth flow, allowing huge communication transmission through single cable networks that can instantly carry terabytes of information. The introduction of submarine cable into the isolated and third- world country locations has reduced the cost of communication access and stimulated increased economic growth.[Chris Stevenson, 2012] Iraq have no submarine cables prior to 2003 and now have two of them landing in Basra Faw and discussion about third cable too.

1. Falcon (cable system)

Falcon is a newly constructed, high-capacity (64 wavelengths per fibre pair) Submarine Cable System connecting Mumbai, India to Suez, Egypt and also providing the first self-healing loop in the Arabian Gulf region. The Network provides multiple landings throughout the Gulf region and the Red Sea. FALCON enable seamless interconnectivity with India's domestic networks, including Reliance's 80,000 km high-speed domestic infrastructure, as well as the FLAG Telecom's Global Network. FALCON was implemented on a phased Segment basis.

- Segment 1: Mumbai – Al Seeb with 1 BU Branch unit for connectivity to Chabahar, Iran.
- Segment 2: Al Seeb – Dubai with 1 BU for connectivity to Khasab, Oman.
- Segment 3: Dubai - Doha
- Segment 4: Doha – Bahrain
- Segment 5: Bahrain – Al Khobar
- Segment 6: Al Khobar – Kuwait
- Segment 7a: Kuwait – Bandar Abbas
- Iraq Segment: Basra project completed by Q2 2012 this we will give Iraq the front Submarines cable Access to the world.
- Segment 7b: Bandar Abbas to Al Seeb.
- Segment 8: Al Seeb to Suez with 7 BUs installed for connectivity to Aqaba, Jeddah, Port Sudan, Al Hodeidah, Djibouti, Al Ghadyah and Salalah.
- Segment 9: Trivandrum to Male with 1 BU installed for connectivity to Sri Lanka.

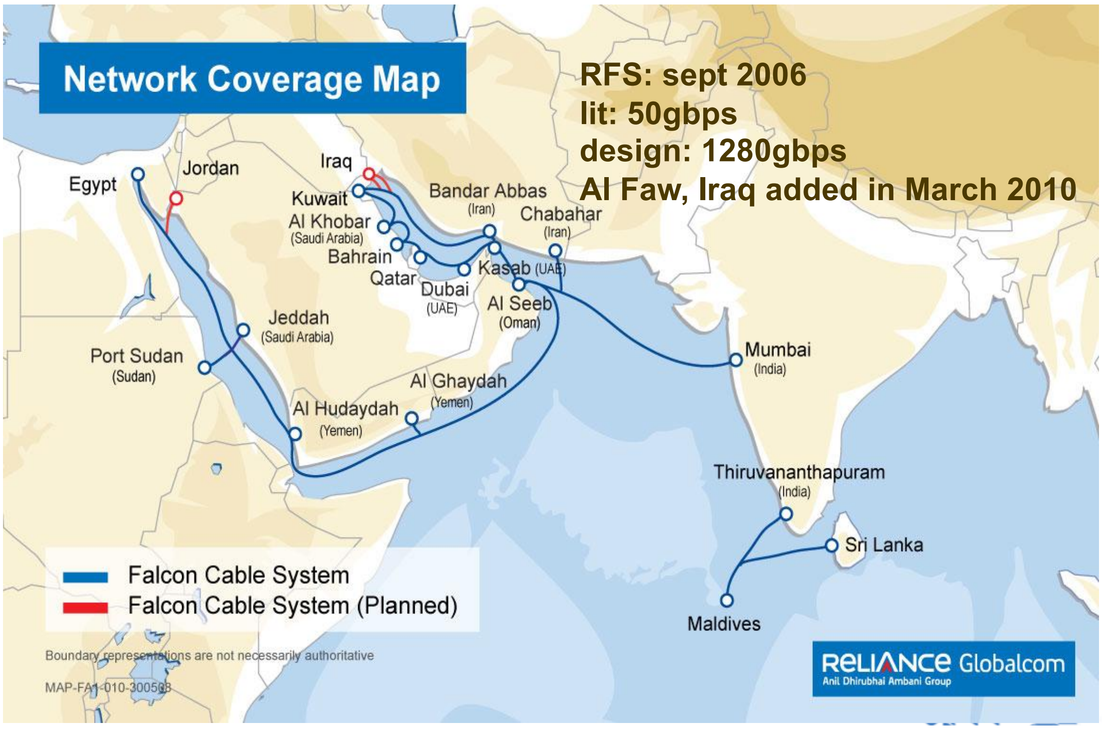


Figure 3.1: Falcon Segments Map

The FALCON Cable System is operated by the FLAG Global Network Operations Centre (GNOC**).**

FALCON provides submarine connections between all the landings identified as well as allowing connectivity to FLAG's other Cable Systems (Flag Europe Asia, Flag Atlantic-1, Flag North Asian Loop) and global network.

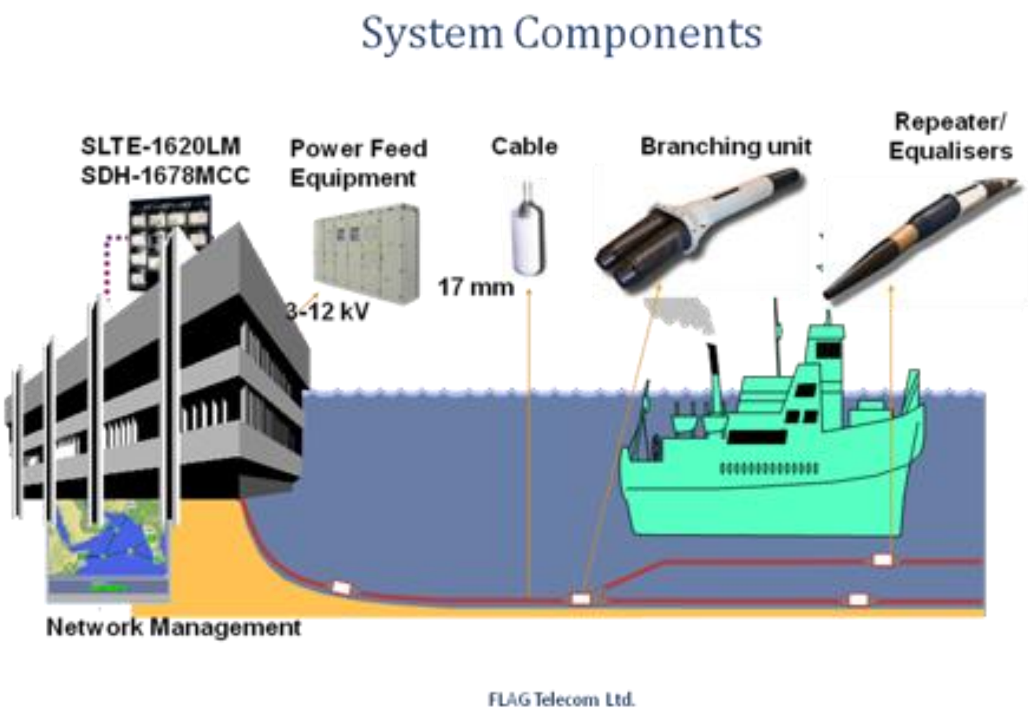


Figure 3.2: System Components

The latest generation of terminal equipment (SLTEs, SDH, PFE and NMS) was implemented to ensure the necessary capacity, performance and reliability requirements.

The Submarine Cable infrastructure between Cable Landing Stations (CLSs) contains fibre types as required (NZDSF, PSC, Reduced Slope), Optical Amplifiers (with different spacing per Segment in order to maintain design/performance requirements) and Equalisers (Active and Passive) to maintain the necessary gain shape.

In the Gulf, the Trunk stations are connected by a 2 fibre pair cable (with 1 fibre pair being dropped for the spur stations. The Mumbai – Al Seeb – Suez Stations are connected by a 4 fibre pair cable again with 1 fibre pair being dropped to each of the spur stations.

Each of the fibre pairs will support 64 x 10 Gbit/s wavelengths thus giving each submarine cable segment a capacity of 2.56 Tera bits per second (T bit/s) on a 4 fp(fiber pair) system, 1,28 T bit/s on the 2fp segments and 640 G bit/s on a 1 fp spur

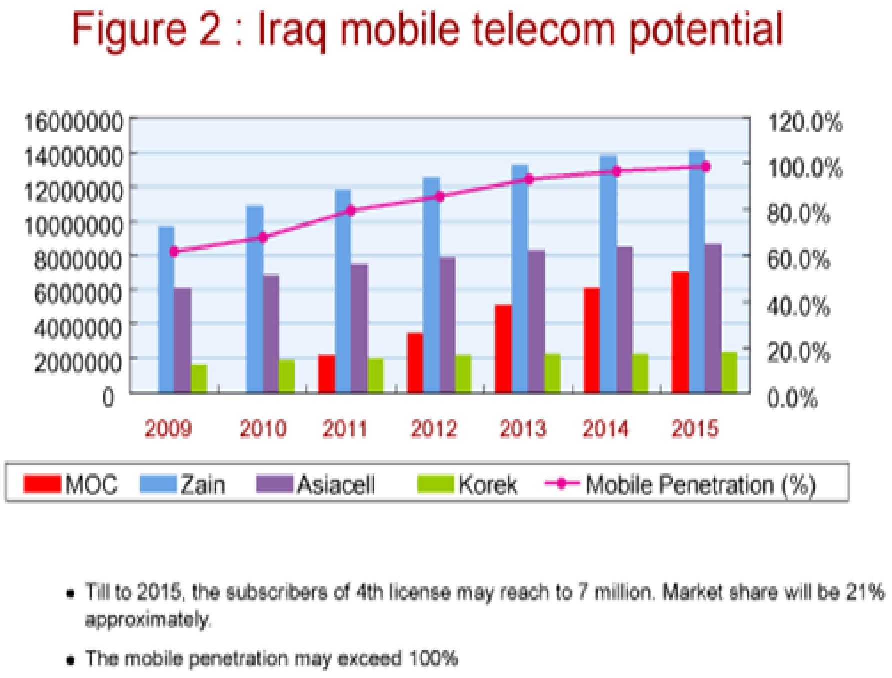


Figure 3.3: Iraq Landing point

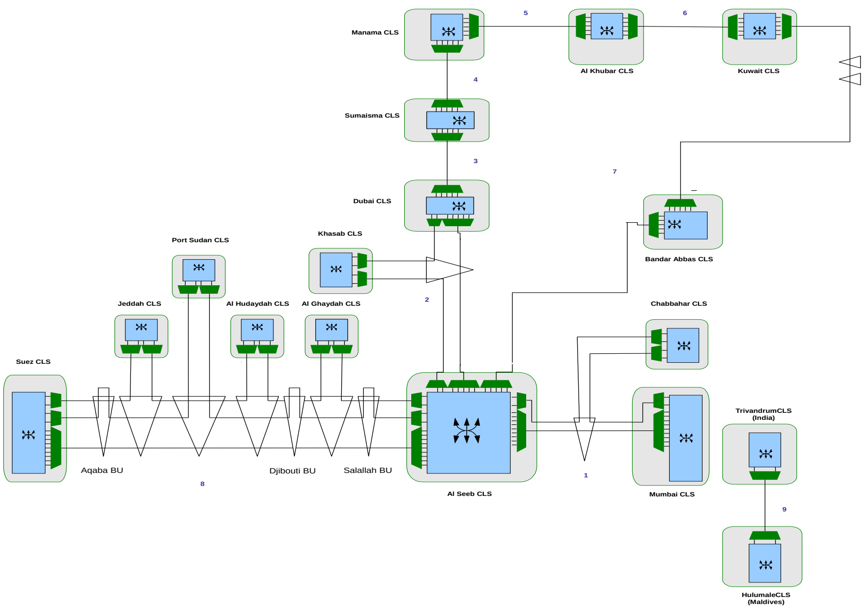


Figure 3.4: schematic configuration of the FALCON Network

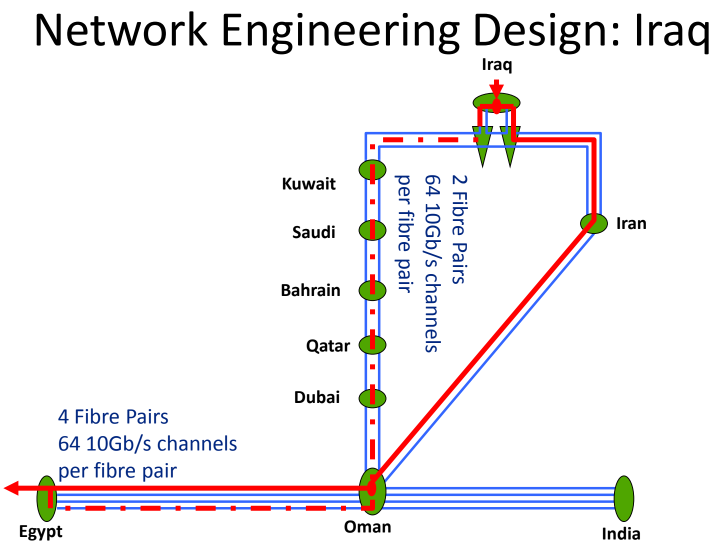


Figure 3.5: Falcon Network Engineering Design

2. GBI (Gulf Bridge International)

The Gulf Ring cable network designed to be highly resilient, employing double landings at the major terminals of Qatar and Fujairah (UAE) with branched landings in Iran, Iraq, Kuwait, Saudi Arabia and Bahrain. The Gulf Ring cable designed as ‘self-healing’– i.e. if the cable is cut, it will continue to work by re-routing the traffic in the other direction round the ring.

Figure 3.6: Gulf Bridge International Cable System (GBICS)

The GBI Cable, will provide direct connectivity to Europe. This connection, the West Route, to pass through the Red Sea to Egypt and then Europe, landing at Mazara in Italy with an onward connection to Milan. This connectivity will provide direct route from the Gulf to major European telecoms hubs (e.g. in Milan) where a full range of wholesale voice and data products can be purchased. As part of the MENA transaction, GBI acquire a direct connection from Fujairah to Oman over GBICS and the MENA Cable. The MENA Cable will also provide the potential to connect to Jeddah in Saudi Arabia, Djibouti, Sudan, Yemen and Egypt.

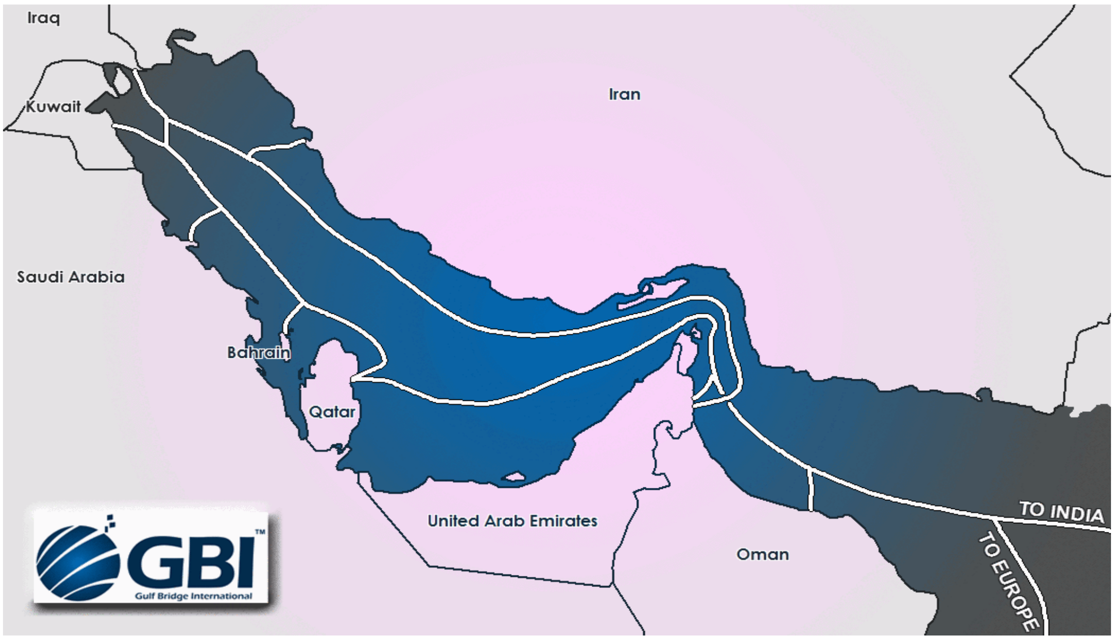


Figure 3.7: GBICS

GBI also have direct link to India, the East Route, which will be built branching off the MENA Cable via a submerged at sea interface off the coast of Oman. This connection enable GBI to provide its customers with wholesale connectivity between the Gulf and India.

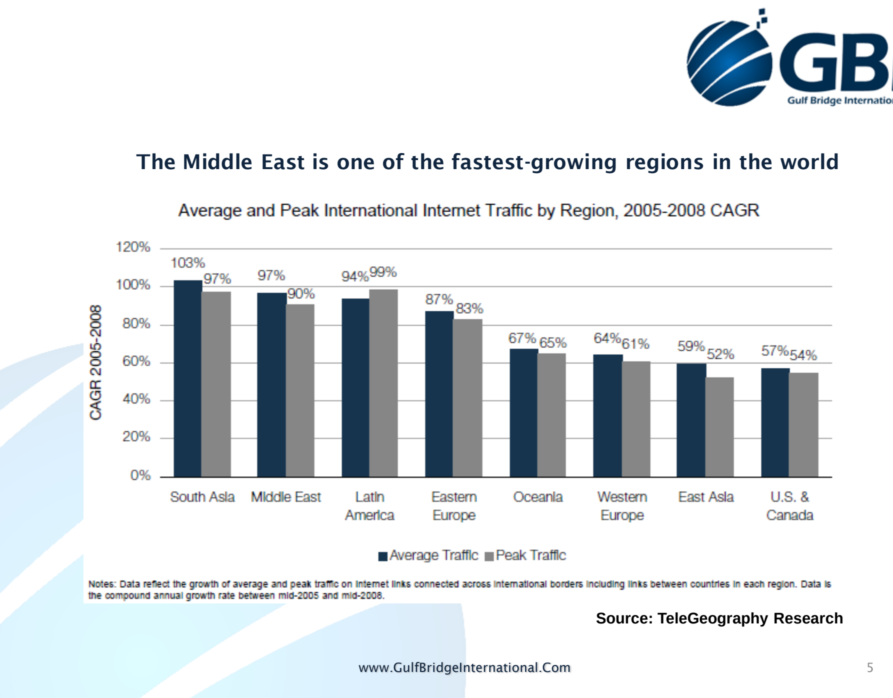


Figure 3.8: The Middle East is one fastest – growing region in the world

In several studies, TeleGeography has found that broadband subscriber growth is the most important driver of demand for international bandwidth services. The countries of the Arabian Gulf region have experienced very strong broadband subscriber growth in recent years and are poised for far more. The number of broadband subscribers increased by 55 percent between 2007 and 2008. This growth rate compares to 18 percent in Asia and 16 percent in Europe during the same time period. Despite the rapid growth, broadband penetration in the Gulf region (14 percent of all households) lags well behind broadband penetration in other regions (e.g., 78 percent in Europe).

This finding suggests that there is much room for sustained, high growth in the Gulf region.

3.3 GBI Deployment Plan and major milestones

- Deploy a submarine fully redundant cable ring linking all GCC countries with an express route to Europe and India.
- Completed implementation with RFS(Ready for Service) by end of Q2 2012 across the whole cable.
- The Lifetime considered in the Design and products is 25 years

Landings Inside the Arabian Gulf

- Double landings in Qatar and UAE,
- Single landings in Saudi Arabia, Bahrain, Kuwait, Iraq and Iran

Landings Outside the Arabian Gulf

- Oman
- India
- Italy (Mazara)

Future Upgrade and expansion plans

- Develop a one-stop-shop to any telecom operator in Europe and the United States. Moreover, will provide restoration services and/or fully restored circuits along the network.
- Landings in Yemen, Djibouti, Sudan, and Jeddah.

3.4 Public Data Networks (PDN)

ITPC completed a rigid infrastructure for IP telecommunication for the use of business and corporate users as well as residential users. This PDN will provide the ground to connect different Iraqi locations enabling communication between them and also provide the backbone for NGN(Next Generation Network) infrastructure by which all services will use the IP technology. The Networks will be expanded and upgraded to reach all cities and towns in Iraq.

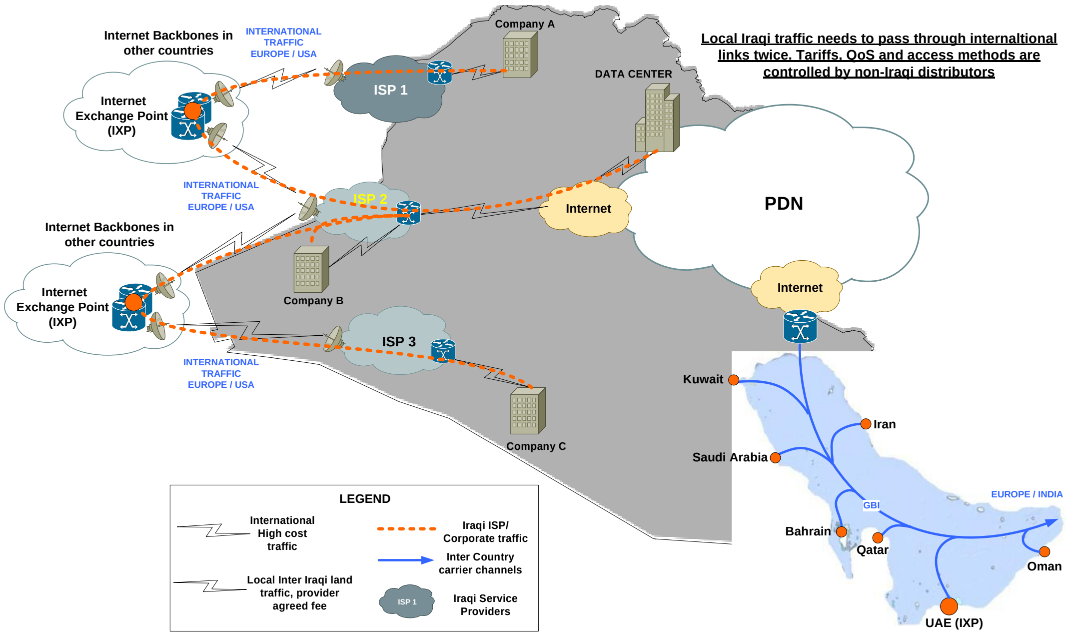


Figure 3.9: Iraqi Internet traffic routes.

The above is referring to the case when no IXP(Internet exchange Point) exists. Company A is connected to ISP1 while Company C is connected to ISP3 in the same country or city. Both companies have resources housed in Data Centre (DC) connected to Internet over ISP2. In order to reach DC from Company A office the traffic should go over expensive VSAT link ISP1 to some international exchange points and then back over VSAT link to ISP2. It becomes very costly for both customers and ISPs when the amount of traffic is significant. As a result, Company A pays a lot and gets slow connection with limited bandwidth and high latency.

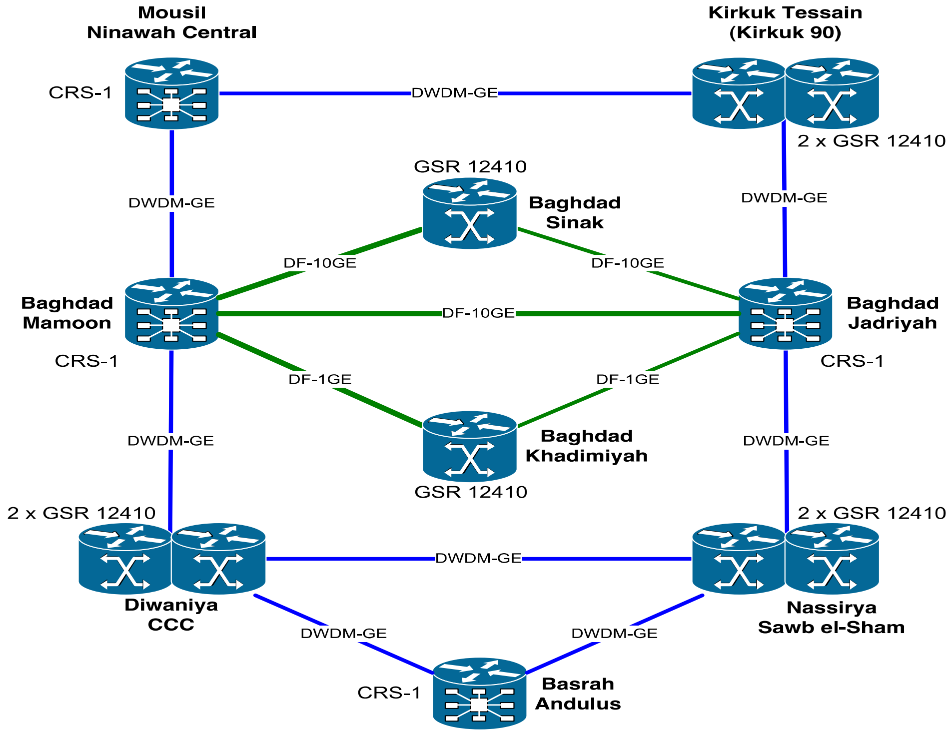


Figure 3.10: ITPC PDN Phase one.

The MoC/ITPC IP PDN network uses Cisco products at the core and at the edge.
Support high speed links such 1 Gbps, 10 Gbps, 40 Gbps and 100 Gbps both as Ethernet interfaces and as IP over DWDM.
The existing IP PDN core network above, only two 10 GE links exist amongst the Baghdad Sinak, Baghdad Jadriyah and Baghdad Mamoon core sites while all the remaining links interconnecting the Mousil, Kirkuk, Nassiriya, Diwaniya, Basra, and Khadimiyah core sites are 1 GE links so all traffic passing from one side of the network to another side will have to cross the core links, consequently core links must be large enough to support most traffic exchanged amongst the various cities in Iraq.
The Existing 1 Gbps core links, although capable of handling today's traffic generated from the PSTN calls, will not be able to handle traffic generating from two million PSTN subscribers next year, furthermore; the utilisation on these 1 Gbps links will be too high to handle additional IP traffic generating from DSL services, FTTx and Ethernet Aggregation and possible future PDN data, voice and video services for enterprises, ministries, private sector. If these links are not upgraded, they finally will get overloaded which dramatically impacts the quality of PDN services like NGN voice service, data services and Internet access.

ITPC should focuses on increasing the bandwidth of the links interconnecting the core sites together and also the edge-core links. The solution also base lines all core products on the CRS3(Carrier Routing System) platform at all core sites. The CRS-3 or higher is the latest Cisco Carrier Routing Switching platform that provides the highest routing performance.

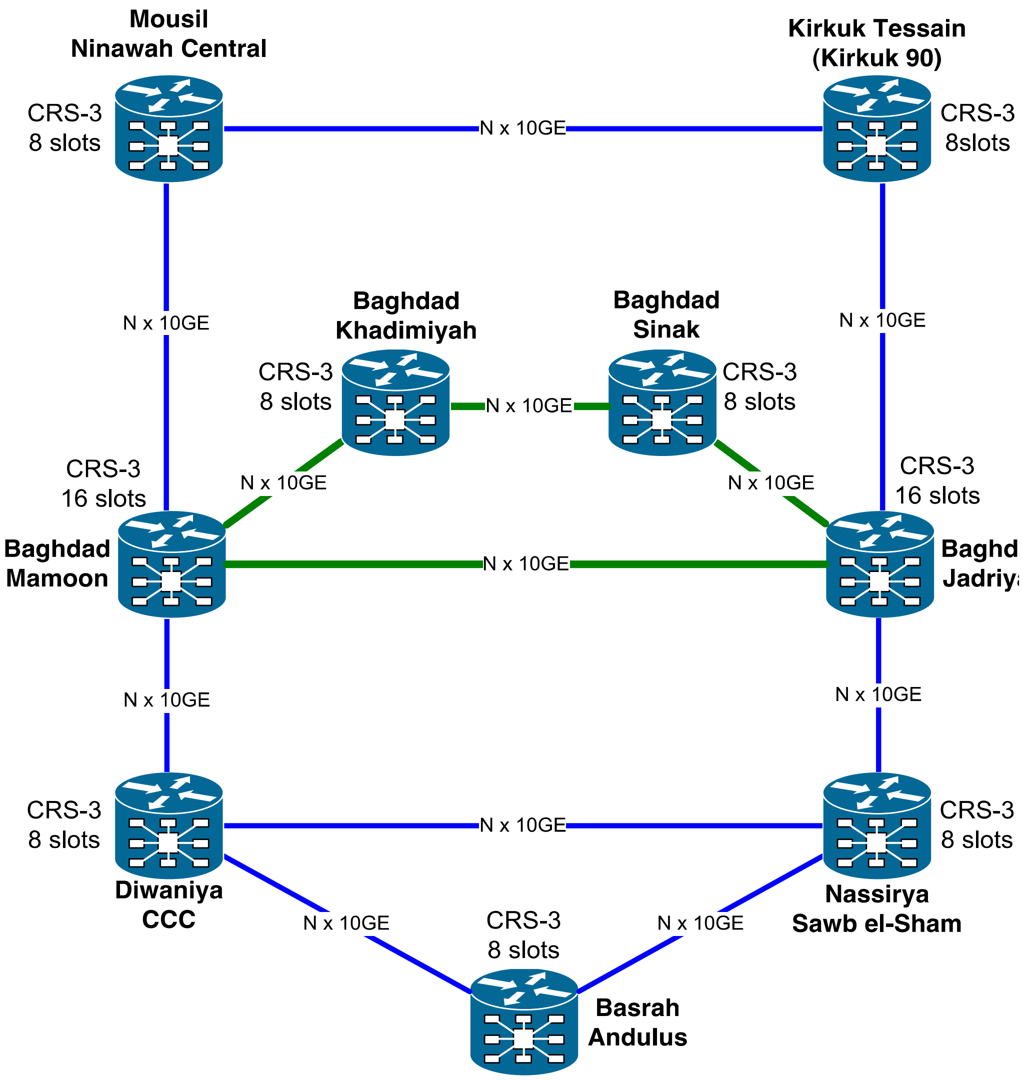


Figure 3.11: PDN core after upgrade (Phase two)

Above shows the proposed core connectivity using n x 10 CRS GE-3links where MoC will have the option to 16 slots scaling from one 10 GE up to fourteen 10 GE links on the same line card.

We can combine them into single logical connection and perform a load balancing arcos every single physical DF/DWDM link to achieve a total bandwidth of 30Gbps. So the total link capacity will be equal to 30GE.

It is not expected that MoC will use all of the fourteen 10 GE ports on each routers from day one and each device will be able to aggregate traffic from PDN customers and deliver it to the core over 10GE links.

3.5 FTTH/FTTC(Fiber To The Home / Fiber To The Curb)

Fiber to The Home and Fiber to Curb will start gaining acceptance in the final frontier of telephone networks, namely: the "last mile," the connection to the home, building and business. Many homes are connected with aging copper with low performance telephone wire that cannot even support DSL connection speeds to allow the phone companies to compete with the cable modems used by CATV(Cable Television) companies for broadband access. The costs of maintaining these old copper cables extremely high and increasing. [The Fiber Optic Association, 2010]

ITPC as the main operator of Landlines realised that the best choice for upgrading the subscriber connection is by fiber to the Business/Building or home (FTTB, FTTH, or FTTx). The possibility of delivering new services (the triple-play of Voice, Internet and TV) and low priced components with new network architectures make FTTx financially attractive for the first time. Ministry of communications should start committing and planning to connect millions of homes, business and government offices with fiber in the near future.

These have to be well planned depending on finding and training of an adequate numbers of Engineers and Technicians. Working with other operating companies or Vendors, municipalities, installers to approved and developed requirements for FTTx training and certification with the goal of providing enough qualified FTTx installation technicians to make these plans possible and reality.

Annual Statistics by Operator

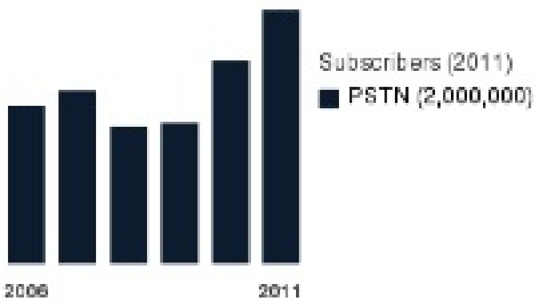
Provider Name	Main Statistic	Reporting Period	2006	2007	2008	2009	2010	2011
Iraq Telecommunications and Post Company (ITPC)	Total lines (PSTN)	December	1,000,000	1,100,000	1,150,000	1,220,000	1,530,000	1,900,000

Annual Country Mainlines Growth

Year	Total lines (PSTN)	Growth (%)	H'hold pen (%)	VoIP subscribers	Growth (%)
2006	1,247,512	11.9%	18.8%		
2007	1,364,512	9.4%	20.0%		
2008	1,082,300	-20.7%	15.5%		
2009	1,108,396	2.4%	15.5%		
2010	1,600,000	44.4%	22.0%		
2011	2,000,000	25.0%	26.4%		

Sources: ITU

Mainline Growth



Sources: *CPA, CMC, ITU*

Figure 3.12: Landline Growth

ITPC signed many contracts for the deployment and operation of two separate fibre-to-the-home (FTTH) network projects in Iraq. The first deployment covers Baghdad, with around 45,000 FTTH lines set to be introduced, with a further 55,000 FTTH lines earmarked to cover Basrah, Wasit, Missan, Najaf and Ninwa in 2011. Other regional contract signed in Nassriya, Diyala and Anbar also KRG have started deploying FTTC/FTTH few years ago.

In March 2011, Mohammed Tawfeq Allawi Iraqi Telecommunications Minister said the government aims to boost fixed-line telephone and internet penetration to about 25% within five years. To achieve this, the government announced plans to invest up to US$500 Million on upgrading and expanding the fixed-line infrastructure that was damaged during the war in the country.

In February 2011 Iraq's communications ministry announced plans to transfer the billing system for landline phones in the country to a prepaid system from February 17th 2011. Zawya reports the ministry contracted China-based telecoms equipment vendor **Huawei Technologies** to develop a program for converting the payment system.

In November 2011 Huawei Technologies won another fixed-line contract, this time to extend fixed-line services to Najaf province. The contract was valued at US$40Million by the chairman of the provincial council's services commission.

In January 2011, **Alcatel-Lucent** won a US$27Million contract to build a fixed-line network in the provinces of Diyala and Anbar. The project is due to start in Q112 and is expected to connect up to 70,000 subscribers in both cities.

3.6 Baghdad Microwave/SDH Network

Baghdad completed a new transmission microwave network that connects 23 sites (Exchanges) via 31 microwave links, which will enable to provide calls, internet, and other data between most exchanges.

The 31 microwave links operate in frequency band 13 GHz with RF channel capacity (7+1) for each one, the interface of each RF is STM-l, Modulation is 128 QAM (Quadreture Amplitude Modulation) . It has the facility XPIC (Cross Polarization Interference Cancelation) that avoids the interference between the radio signals and also should have engineering order wire (O.W) and 2M Way side.

The solution consists of Ericsson Marconi LH(Long Haul) Solution, which has lowest power dissipation on the market, with up to 9+1 STM1 capacity per rack and 18+2 STM1 per link, and complies with the standards and recommendations of national and international organisations such as ETSI, ITU-T (CCITT and CCIR), ANSI(American National Standard Institute) and CEPT(European Conference of Postal and Telecommunication Administration).

The proposed Management System for Microwave and Optical Networks is Based on industry standards with an open and adaptable architecture that enables the rapid introduction of new services, minimizes integration costs and secures application interoperability. Optical Add Drop Multiplexer, withASTN/ASON feature is included for redundancy to provide automaticTraffic re-routing and switching during MW link failure, eliminating the needs for manual recovery in such situation.

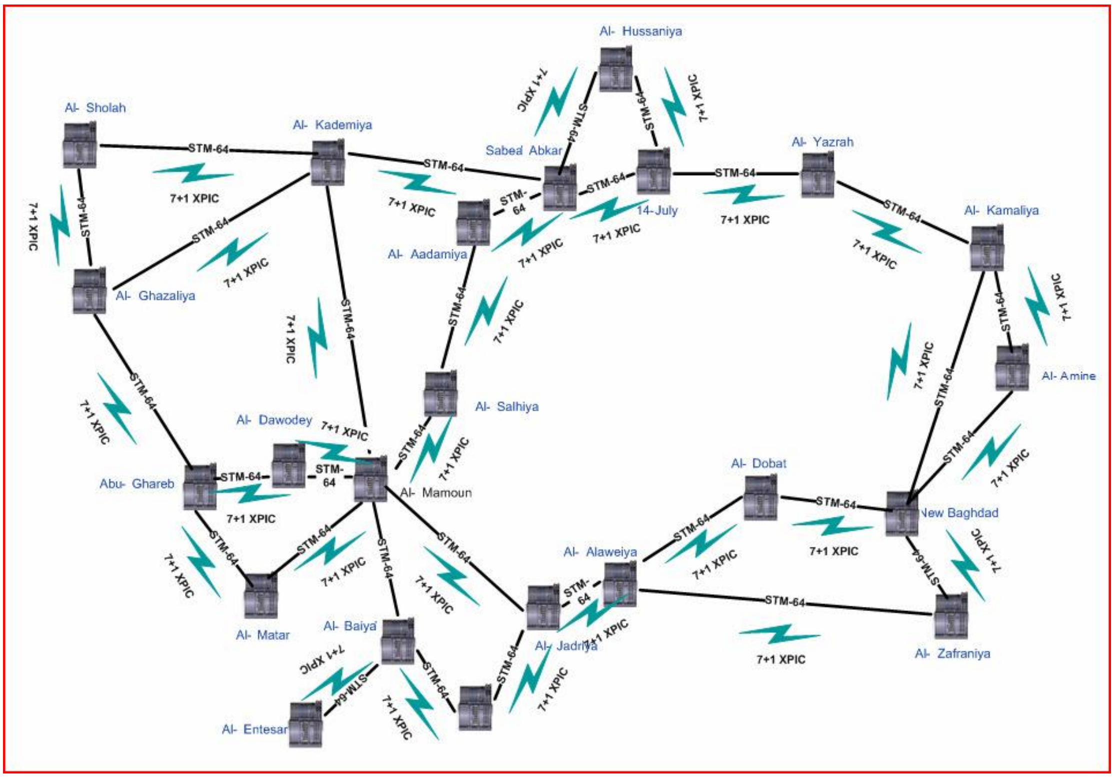


Figure 3.13: Network Overview 31 MW links, 31 Optical STM-64 links and 23 OMS

3.7 GSM 4th Mobile Operator.

Iraq’s economy is dependent on oil, with increasing stability taking place after Operation Iraqi Freedom. Its GDP(Gross Domestic Product) per capita is $3600 (2009). [CIA fact book, 2013]

Currently there is a penetration level of 5.6% in the fixed telephones and 71% in the mobile segment. The market potential is diversified, as there is room for growth on the fixed, mobile, and broadband levels.

Overall macro and micro economic investment factors have been analysed to provide a holistic perspective to subscribers' forecast. Some of the key indicators are mentioned below:

Economic Growth: The overall economic growth was 4.3% in 2009.
Telecom revenues are expected to increase as there is a strong government initiative to boost the sector. [CIA fact book, 2013]

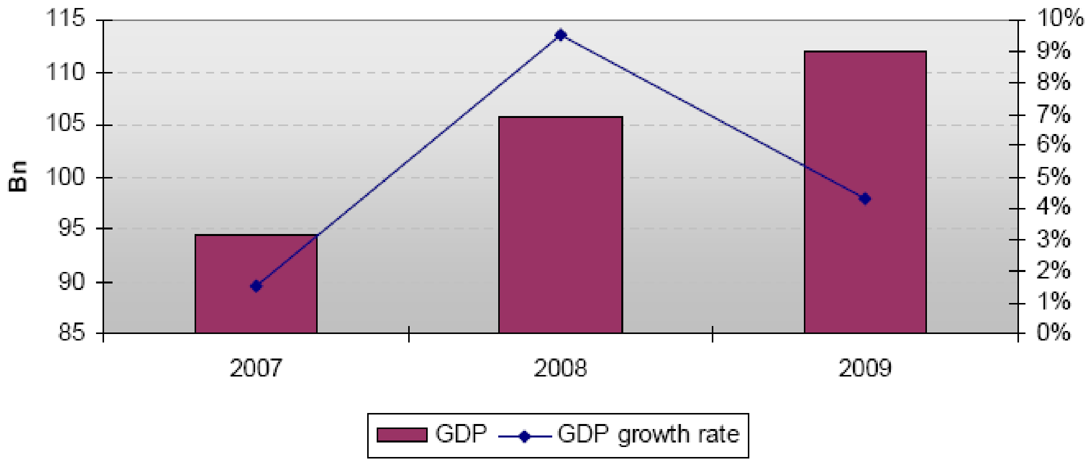


Figure 3.14: GDP Growth Rate

Currently the mobile market is divided between three major operators, namely Zain Iraq, Asiacell, Korek Telekom. Sanatel is a fourth operator that is operating in northern Iraq, which have a subscribers' base of only 495K subs [Telegeography, 2012]

Political instability impeded growth to reach its zenith in the country; however, starting from 2009 more stability and security improved, and the future growth is foreseen in the market as increased investment by international telecoms companies and gradual liberalisation of the sector has been taking place. In the passed period there has been an aggressive increase in the number of wireless subscribers, and this is foreseen to continue.

The Total Country Connectivity Measure results for 2009 revealed the continued leadership of GCC countries. **UAE** maintained the top spot (with a score of 352%), followed by **Saudi Arabia** (286%), **Qatar** (254%), **Bahrain** (250%), **Libya** (246%), **Kuwait** (201%), **Oman** (189%), **Algeria** (161%), **Lebanon** (155%), **Morocco** (149%), **Jordan** (148%), **Tunisia** (145%), **Syria** (142%), **Egypt** (140%), **Palestine** (109%), **Iraq** (100%), **Yemen** (66%) and in last place **Sudan** with a TCCM value of 51.2%. [Arab Advisory Group, 2010]

The key business challenge for all mobile operators is generating the maximum return on their technological investment over the longest period of time. Operators need to continue to reduce the production cost of traffic and get obtain more capacity from existing investments, through innovative solutions that reduce the total cost of ownership while avoiding any barriers to future business development and growth. Operators that have established a market-leading position for voice and SMS services will want to maintain or improve this position in the emerging mobile data market. [Ericsson, 2009]

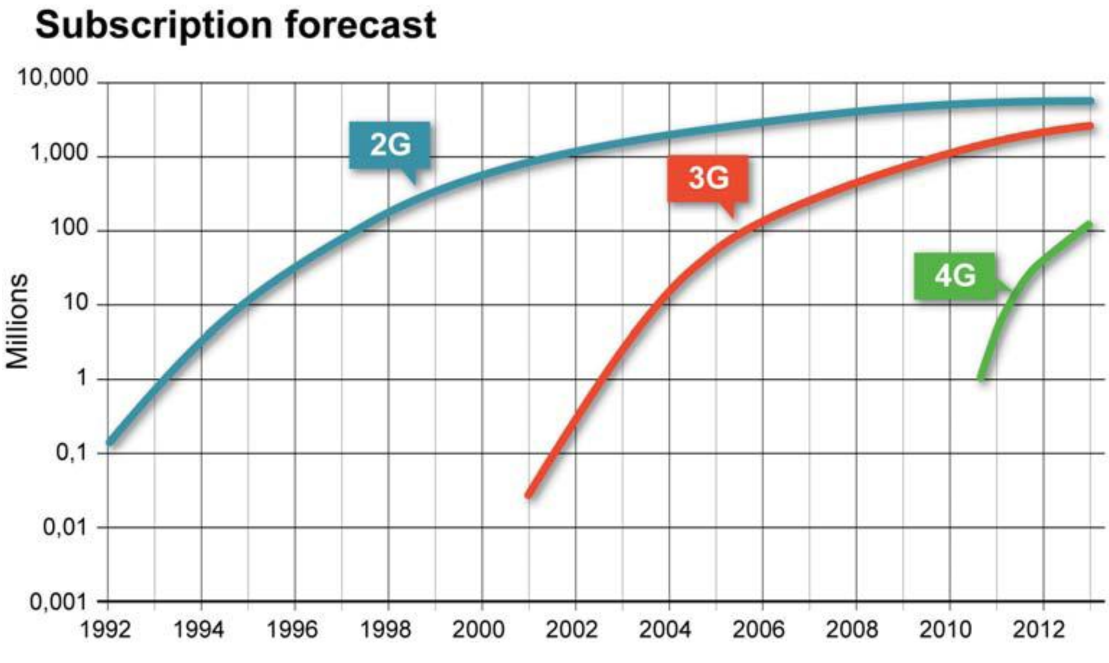


Figure 3.15: The 3GPP family of standards, GSM, WCDMA and LTE, will continue to coexist into the foreseeable future.

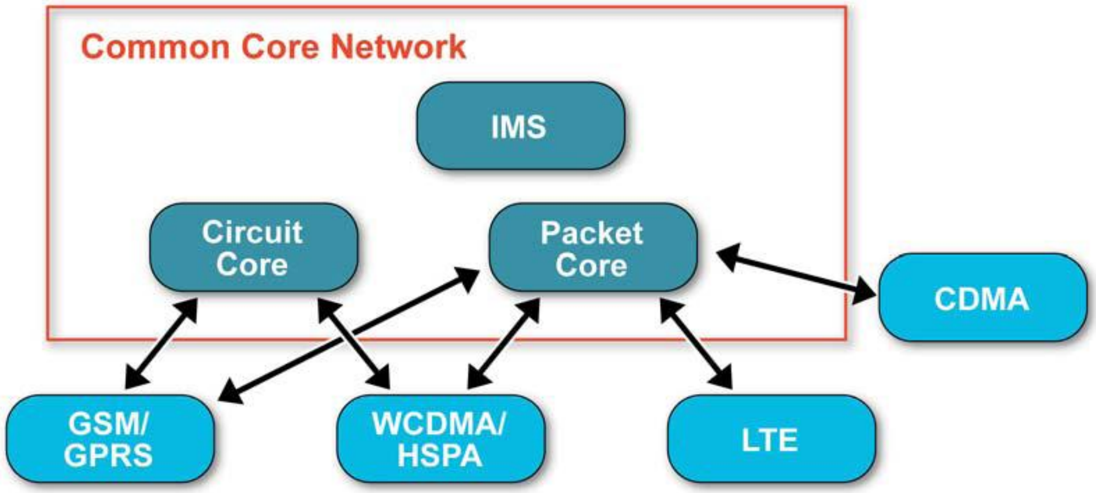


Figure 3.16: The common core network will enable roaming between GSM/EDGE, WCDMA/HSPA, LTE and CDMA.

It is clear that the three generations of 3GPP radio technologies will continue to coexist for many years to come, and operators will need to manage these generations in parallel. Features such as multi-standard radio and increased integration of O&M systems support this requirement by, for example, enabling dynamic traffic load sharing across the different radio networks.

The strong business case for HSPA(High Speed Packet Access) is simply another point of evidence of the continuing success of 3GPP standards, and prepares the way for exciting new possibilities such as LTE.

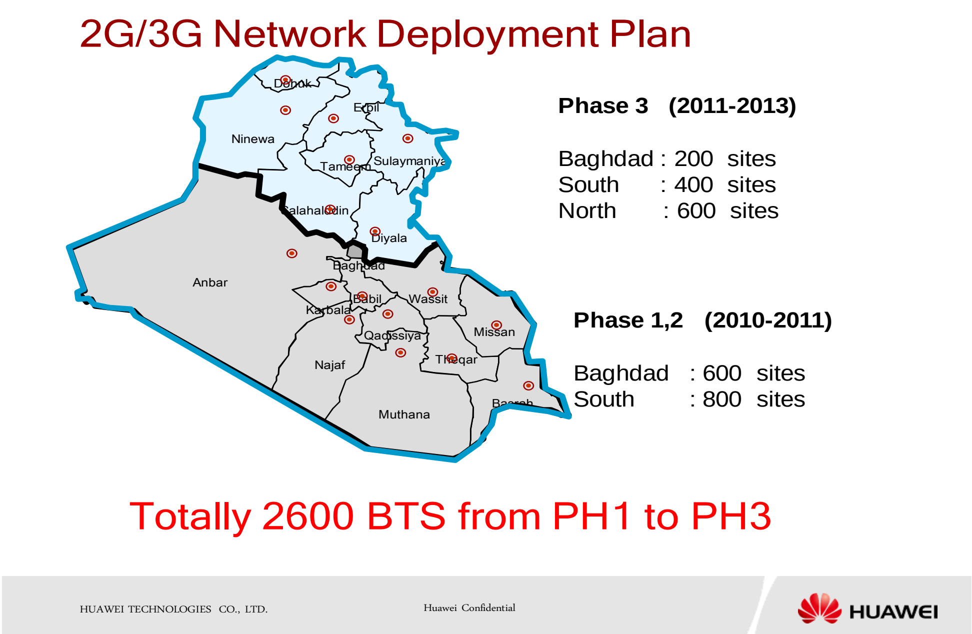


Figure 3.17: Networks Deployment phases

If the MoC/ITPC 4th license launches by 2013 then till 2015, the subscribers of 4th license may reach to 7 million. Market share will be approximately 21% for MoC. The mobile penetration may exceed 100%.

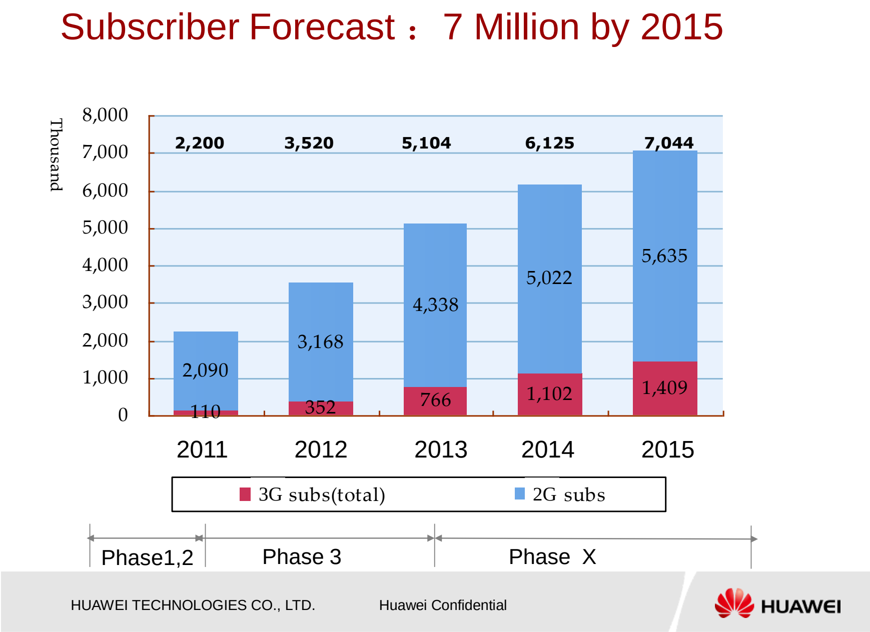


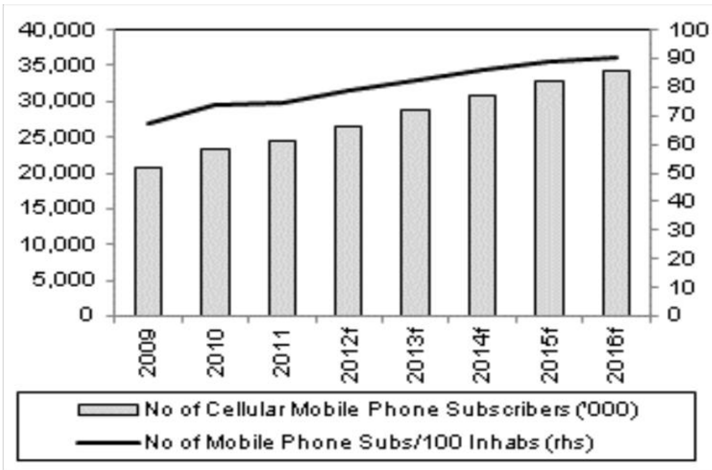
Figure 3.18: Subscriber Forecast

Mobile penetration in Iraq is on the rise, as the market has still did not reached saturation levels. Mobile market growth is expected grow more aggressively as the political situation becomes more stable.

Iraq's mobile market grew by 3.2% q-o-q(Quarter On Quarter) during the three months to March 2012 to 23 Millions subscribers, according to market data published by the country's three mobile network operators - **Zain Iraq**, **Qtel**-owned **Asiacell** and **France Télécom**-backed **Korek Telecom**.

Industry Trends - Mobile Sector

2009-2016



f = BMI forecast. Source: BMI

Figure 3.19: Subscriber Forecast

A number of factors underpin our medium-term growth expectations. First is the anticipated issuance of a fourth mobile operating licence. Although a new mobile operating licence was expected to be issued in early 2011, the issuance was delayed. However, Iraqi Minister of Communications Mohammed Allawi announced in October 2011 that the license would be auctioned in 2012. [BMI, 2012]

Key growth triggers for the last 1-2 years have been:

- Increased focus on developing the infrastructure.
- Increased focus on service levels.
- Improved overall economic situation

Quarterly Subscribers by Operator

Provider Name	Subscribers	Mar 2011	Jun 2011	Sep 2011	Dec 2011	Mar 2012	Jun 2012
Asiacell	Total	8,306,206	8,503,000	8,700,412	8,978,656	9,389,277	9,532,106
Korek Telecom	Total	2,690,000	2,740,000	2,850,000	3,035,000	3,347,000	3,640,000
SanaTel	Total	0	0	0	0	0	
Zain Iraq (formerly MTC Atheer)	Total	12,065,000	12,294,000	12,413,000	12,435,000	12,497,000	12,863,000

Notes: TeleGeography was unable to ascertain when SanaTel ceased trading, so subscriber figures are estimates.
Sources: estimates, operators

Annual Country Subscriber Growth

Year	Total	Growth (%)	Pop. Pen. (%)	3G	3G Growth (%)	4G (LTE)	4G (LTE) Growth (%)
2006	6,642,891	91.3	23.1	0		0	
2007	12,775,000	92.3	43.2	0		0	
2008	17,757,470	39.0	58.4	0		0	
2009	20,067,154	13.0	64.2	0		0	
2010	22,834,498	13.8	71.3	0		0	
2011	24,448,656	7.1	74.4	0		0	

Quarterly Country Subscriber Growth

Period	Total	Growth (%)	3G	3G Growth (%)	4G (LTE)	4G (LTE) Growth (%)
Mar 2010	20,849,319	3.9	0		0	
Jun 2010	22,131,252	6.1	0		0	
Sep 2010	22,262,166	0.6	0		0	
Dec 2010	22,834,498	2.6	0		0	
Mar 2011	23,061,206	1.0	0		0	
Jun 2011	23,537,000	2.1	0		0	
Sep 2011	23,963,412	1.8	0		0	

Figure 3.20: Subscribers Growth

3.8 Next Generation Networks (NGN)

Ericsson has deployed seven NGN switches for 740k subscribers for the whole of Iraq and also Huawei has deployed NGN switches supporting 80k subscribers in Baghdad and 20k subscribers in Basrah.

ITPC have 374 Sites Equipped with capacity of 2M lines of which around 1.2M TDM lines are in Service.

Iraq is moving towards Next Generation Networks (NGN) voice made its mark in the international bypass first.

Most of the long haul carriers deployed the technology in various countries around the world. As a natural extension to that, NGN voice penetrated the national long distance networks. The steady migration to NGN voice has reached a point where we have hundreds of billions of minutes being transported over long distance NGN voice networks each month. Nearly all incumbents and mainstream operators around the world are in the process of migrating from legacy to NGN networks. On the access side, consumer VoIP services are proving to be a major catalyst in the convergence of services in form of triple play. When seen from a broader angle, triple play is only a part of an even larger story where all services (voice, data, video) will be unified across an all-IP network, independent of the access network.

Table 3.1: ITPC Current Suppliers

Supplier	Total No#. Equipped Lines	Type f Access Node	Total No#. Of Sites	%
Ericsson	740K	MSAN/EAR	27	37%
ALU	345K	CS AN	29	17.3%
Samsung	274K	CS AN	117	13.7%
ZTE	572K	CS AN	119	28.6%
Huawei	25K	CS AN	9	1.25%
Others	44K	~WLL	73	2.15%
Total	**2M Lines**		**374**	

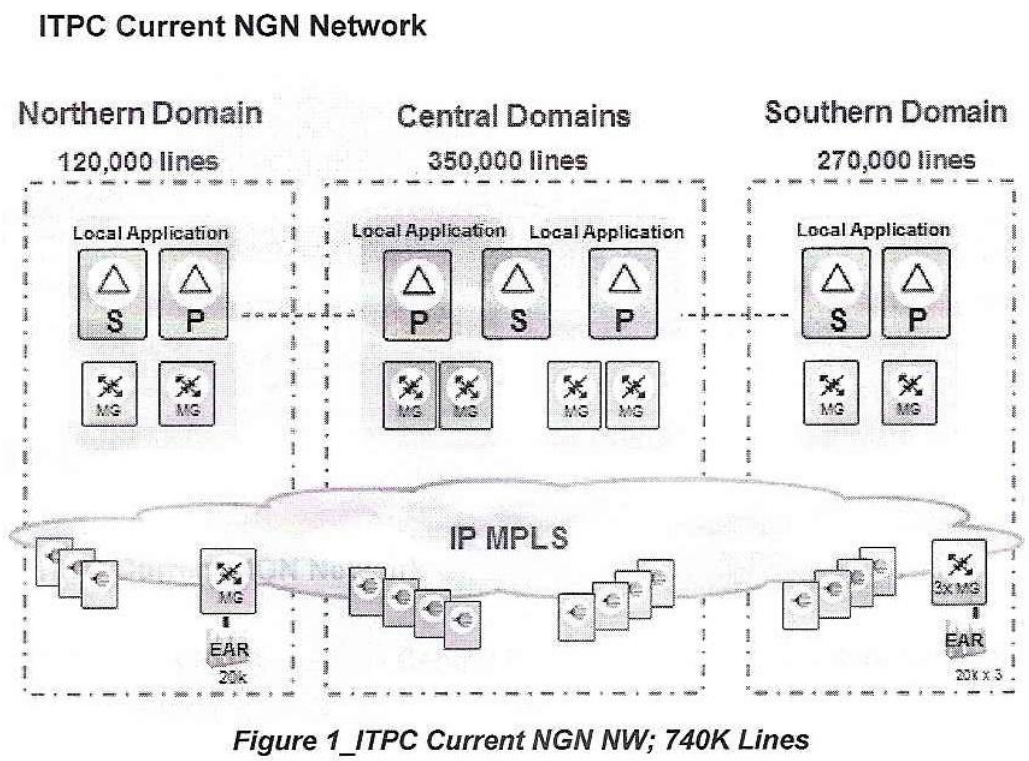


Figure 3.21: ITPC Current NGN Networks

Legacy TDM network equipment is reaching obsolescence and are not fully covered by support and maintenance contracts. The ecosystem around voice switches has transitioned to IP. Therefore the motivations for NGN voice today are not necessarily just the advanced services and reduced OPEX but rather to move the network to the next stage and get rid of 20 year old equipment. Furthermore of course, the carriers are doing that with NGN equipment. Until a few years back, only small providers were deploying NGN voice. This allowed several small vendors to develop and enhance their technologies. Now that many have demonstrated that NGN voice is working well and can be used for carrier-grade deployment, and that it reduces OPEX, larger carriers have moved ahead with their network development plans. This holds true for BRIC(Brazil, Russia, India, China) countries too. ITPC have many NGN projects underway and the decision made all networks to be NGN/IMS.

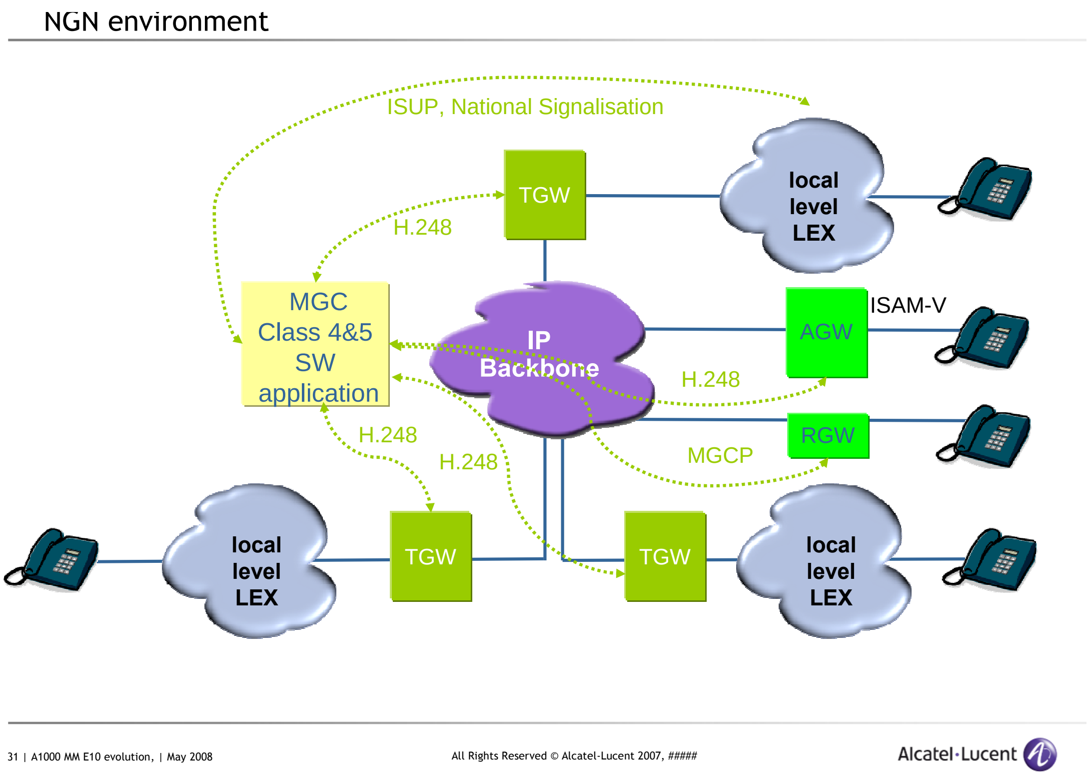


Figure 3.22: NGN Environment

3.9 IMS (IP Multimedia Subsystems)

IMS is recognised as the ultimate architecture and only future standard of the core network by all the standard organisations like TISPAN, ITU, 3GPP, etc.

The IP Multimedia Subsystem (IMS) standard defines a generic architecture for offering Voice over IP (VoIP) and multimedia services. It is an international, recognised standard, first specified by the Third Generation Partnership Project (3GPP/3GPP2) and now being embraced by other standards bodies including ETSI/TISPAN. The standard supports multiple access types – including GSM, WCDMA, CDMA2000, Wireline broadband access and WLAN.

For users, IMS-based services enable person-to-person and person-to-content communications in a variety of modes – including voice, text, pictures and video, or any combination of these – in a highly personalised and controlled way. [Ericsson, 2004]

All the new services (IPTV, HD conference, etc) and new access types (FTTx, Wimax, LTE, etc) is based on IMS architecture according to the standard.

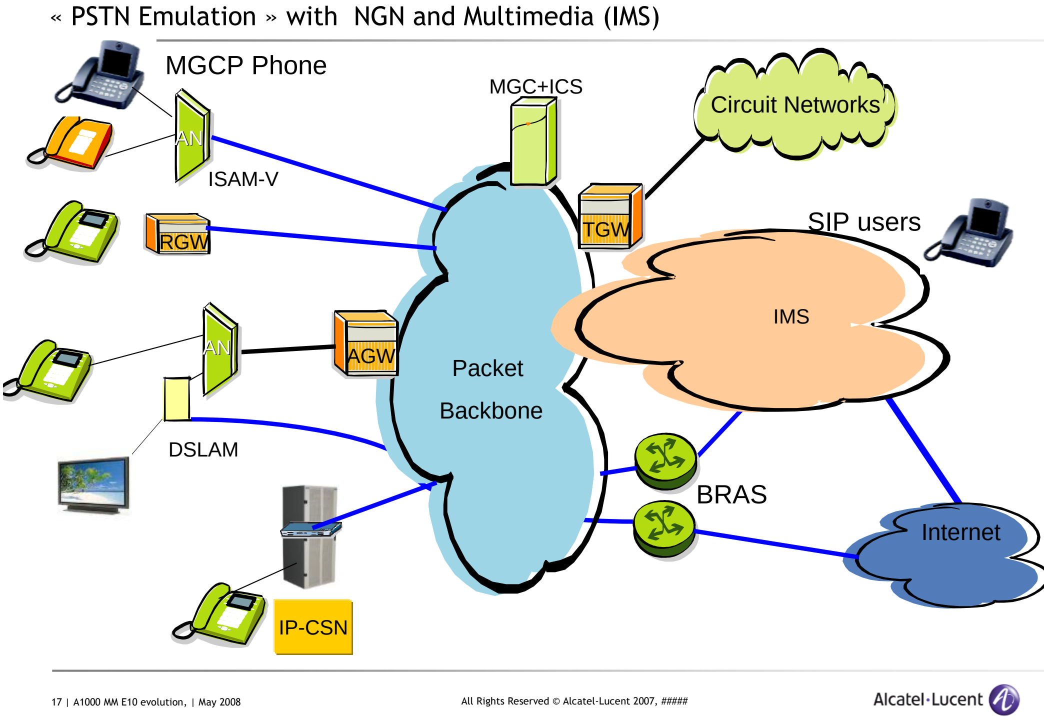


Figure 3.23: IMS

The Only choice to realize FMC (Fixed and Mobile convergence) for core network.

Top operators (VDF, FT, DT, Telefonica, etc) is going for IMS.

IMS is the next generation of NGN, makes the network more flat with a unified core, easy to introduce new services, regardless of access type.

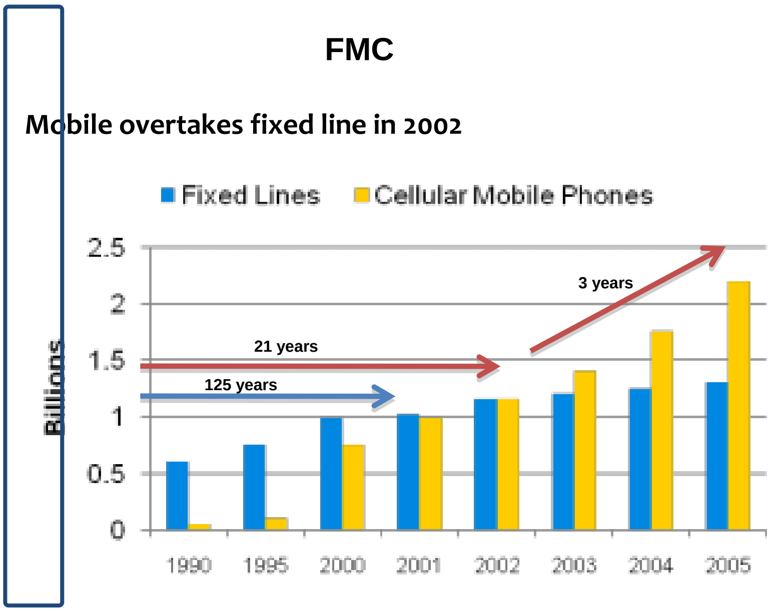


Figure 3.24: Fixed Mobile Convergence

One of the biggest hindrances to the development of internet and other IP-based services in Iraq is the lack of capacity. Whatever technology broadband suppliers in the future choose to employ in Iraq, be it WiMAX, ADSL, FTTH or 3G, they will need backhaul capacity and sufficient bandwidth both internationally and within the country, linking towns and cities to high-speed data. [BMI, July 2012]

3.10 Data Centre

Data Centre is home to the computational power, storage, and applications necessary to support Hosting services. The data centre infrastructure is central to the ICT architecture, from which all content is sourced or passes through. MoC should start implementing a data centre infrastructure design, based on latest technology best practices – carefully considers performance, resiliency, and scalability required.

The important aspect of this data centre design is flexibility for quickly deploying and supporting new services. By designed a flexible architecture that has the ability to support new applications in a short time frame can result in a significant competitive advantage for IQ National Domain. Such a design requires solid initial planning and thoughtful consideration in the areas of port density, access layer uplink bandwidth, true server capacity, and oversubscription, which needs to be discussed in more details.

The data centre network design should be based on a proven layered approach, which has been tested and improved over the past several years in some of the largest data centre implementations in the world. The layered approach is the basic foundation of the data centre design that seeks to improve scalability, performance, flexibility, resiliency, and maintenance. Also Mobile data-related usage has recently experienced unprecedented growth that is likely to continue. Simultaneously, customer quality expectations are increasing as new smart phones and data services are introduced to the market.

Data centre businesses are currently less important to some players or ISP, they will become more central to operators' converged service models over time.

3.11 Networks Operation Centre (NOC)

ITPC need to build new Network Management System or centre that gives end to end solution for monitoring the entire network for Iraqi Telecommunication and Post company:

- Consolidated view end-to-end service view from all element across the vendor.
- Collection of all events from managed devices.
- Advanced filtering and customised views.
- Real-time alarm/event surveillance.
- Operational view based alarm browser and event browser.
- Automatic alarm “Push” feature and event suppressing including alarm correlation.
- Alarm acknowledgement and clearing.
- Alarm filtering and severity redefinition.
- Threshold crossing alert.
- Alarm notification service and alarm pop-up window
- Historical alarm management
- Alarm and event statistics and reporting
- Fault diagnosis and localization
- Service Management and Operations
- Resources Managements and options

The NOC can be utilised to monitor, manage and troubleshoot problems in all telecom networks so building proper dimensioned NOC can be a new source of revenue for ITPC.

The NOC should provides a structured environment that effectively coordinates operational activities with all participants and vendors related to the function of the network.
The NOC typically provide support twenty-four hours a day, seven days a week to keep the network up and running reliably to meet customer satisfactions and company performance indicators.

3.12 IGW (International/Internet Gateway).

There are two different Gateways names in Iraq one called International Gateway(IGW) for the international Voice Traffic and which is owned by ITPC and the second one owned by SCIS called Internet Gateway.

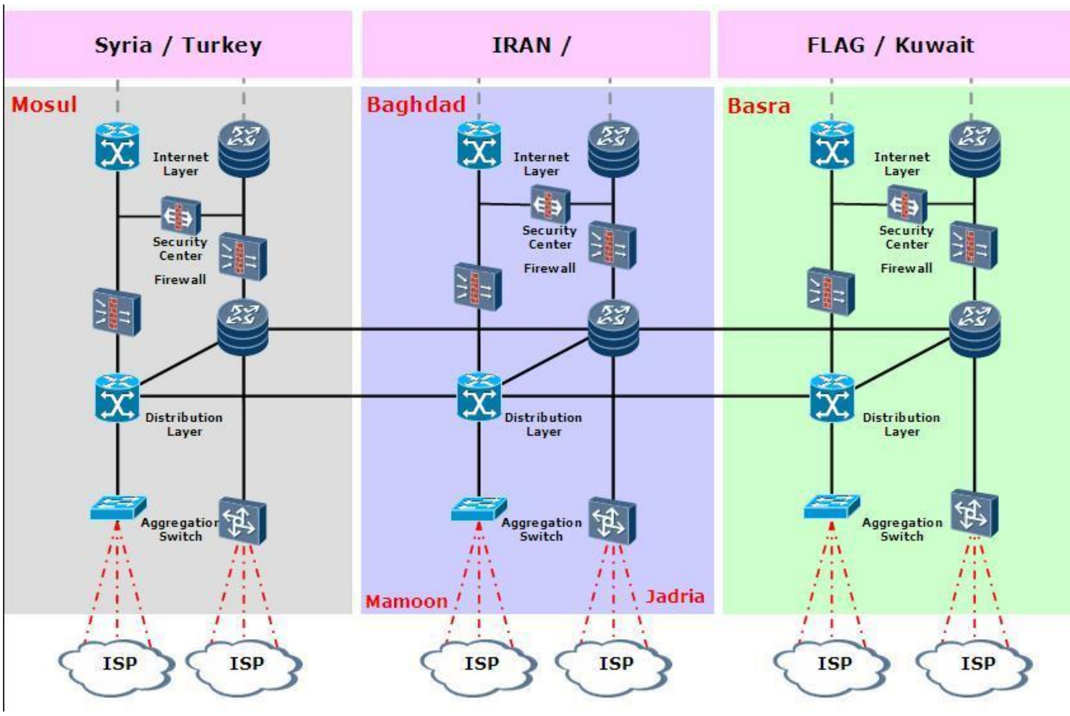


Figure 3.25: International Gateway (IGW)

3.13 SCIS Internet Gateway

ITPC implementing international voice gateways to carry all international traffic to all operators with different types of traffic, Voice on TDM, Voice on IP and SMS.

The main IGW (soft switches and media gateway) in three zone centres (Baghdad in Dhubat) , Mosel and Basra and four remote media gateway (Erbil , Sulaymaniya, Karbala and Mammon in Baghdad) with capacity of 6 STM 1 each soft switch can Handle 308 million minutes / month with redundancy of other two soft switches.

IGW also contains SMS gateway and billing system with centralised management system in Baghdad . It supports MMS service and fraud management system.

The systems will introduce new SMS gateway and new billing gateway
T-one server, which connect to three IGW for fraud detection. Each IGW will be connected to three carriers at least by using least cost route either by using the optical cable or by satellite for redundancy in addition to the direct international connection with the border countries Kuwait , Jordan , Turkey , Syria and Saudi Arabia.

Currently there are three IGW provided by CDN company which are located
In Baghdad (Jadiriya) , Basra and Krikuk and all are connected to the mobile operators switches by optical cable with redundancy microwave links . The carriers are connected to IGW by the optical cable which is connected to border countries (Kuwait , Jordan , Turkey) and the main POP of carries based in London.

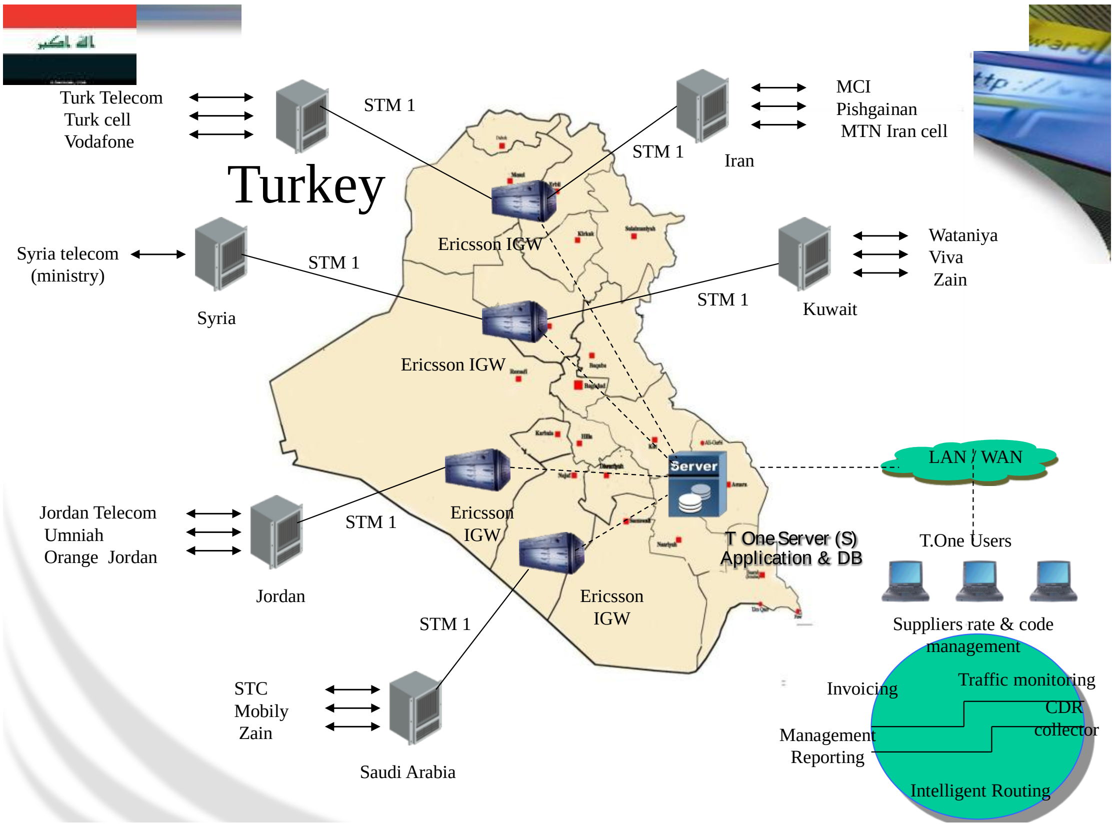


Figure 3.26: ITPC International Gateway

3.14 IXP (Internet exchange Point)

An Internet exchange point is a physical infrastructure through which Internet service providers (ISPs) exchange Internet traffic between their networks. IXPs reduce the portion of an ISP's traffic which must be delivered via their upstream transit providers, thereby reducing the average per-bit delivery cost of their service. Furthermore, the increased number of paths learned through the IXP improves routing efficiency and fault-tolerance.

The primary purpose of an IXP is to allow networks to interconnect directly, via the exchange, rather than through one or more 3rd party networks. The advantages of the direct interconnection are numerous, but the primary reasons are cost, latency, and bandwidth. Traffic passing through an exchange is typically not billed by any party, whereas traffic to an ISP's upstream provider is. The direct interconnection, often located in the same city as both networks, avoids the need for data to travel to other cities (potentially on other continents) to get from one network to another, thus reducing latency. The third advantage, speed, is most noticeable in areas that have poorly developed long-distance connections. ISPs in the Middle

East have to pay between 10 or 100 times more for data transport than ISPs in North America, Europe or Japan. Therefore, these ISPs typically have slower, more limited connections to the rest of the internet. However, a connection to a local IXP may allow them to transfer data without limit, and without cost, vastly improving the bandwidth between customers of the two adjacent ISPs.

Internet traffic exchange between two participants on an IXP is facilitated by BGP(Border Gateway Protocol) routing configurations between them. They choose to announce routes via the peering relationship - either routes to their own addresses, or routes to addresses of other ISPs that they connect to, possibly via other mechanisms. The other party to the peering can then apply route filtering, where it chooses to accept those routes, and route traffic accordingly, or to ignore those routes, and use other routes to reach those addresses.

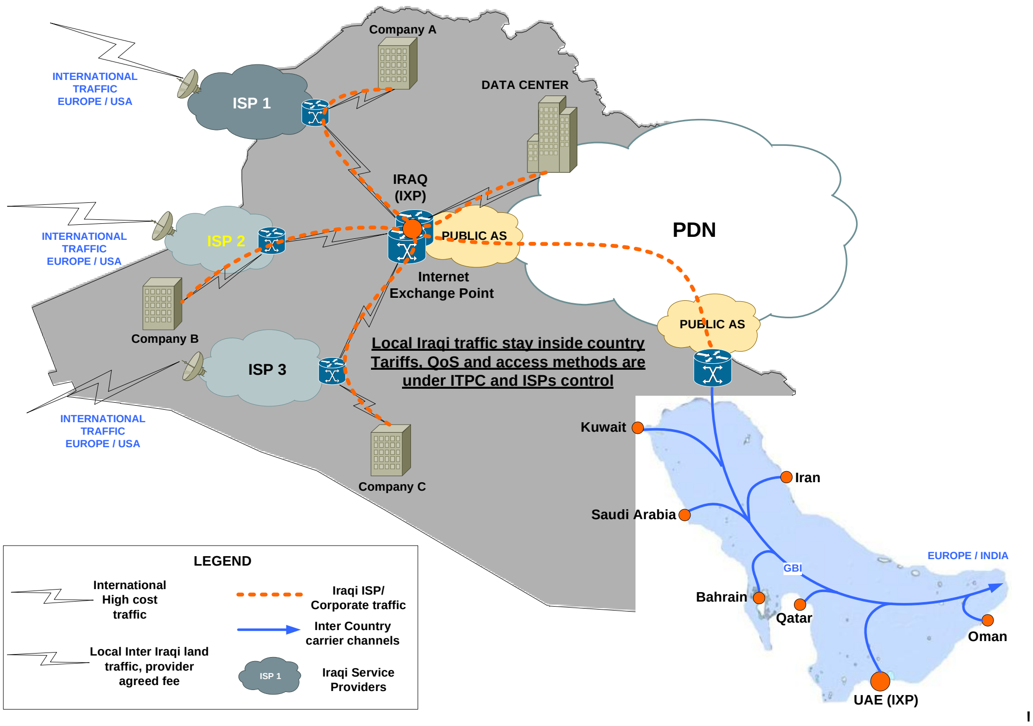


Figure 3.27: Iraqi Internet traffic routes with local IXP

The main benefit of local IXP in Iraq is direct interconnection between all participants who form Internet space in Iraq. Due to direct links between ISPs local Iraqi Internet speed tends to LAN(Local Area Network) speed therefore Internet services becomes more accessible for end users.

Looking to the future, Iraqi IXP can become a key point for connectivity with other International IXP like UAE IXP, Iran and Beirut IXP. A submarine fiber optical cable. This gives ITPC an opportunity to have broadband carrier connectivity with other Telco and ISPs from Middle East, Asia and Europe. The best place to terminate such International link is an IXP, so ITPC can control traffic flow, quality of service and regulate tariffs for international data, voice and video services.

3.15 3G/4G

There is, as yet, no 3G market in Iraq. **BMI**[Business Monitar International, 2012]believes mobile content services are limited in the country, with mobile subscriptions concentrated on prepaid, and within that on basic voice services.

Zain Iraq has said that the introduction of 3G services will be an important part of its strategy. The operator is already testing the technology and is awaiting a licence from the government to provide 3G services. In March 2012, Korek said it aims to launch 3G services in 2012, and is awaiting the government's release of the required spectrum.

Zain contracted Ericsson to optimise, modernise and manage both Zain's IT operations and its mobile network across 3,700 sites, including in the Kurdistan region where Zain recently launched services. Zain states that it chose a managed services contract to focus on its customer-facing activities and benefit from improved network efficiency. [BMI, July 2012]

Korek Telecom selects Ericsson to upgrade and expand its network in the country. The agreement will also prepare Korek's network for 3G and LTE. Under the terms of the agreement, Ericsson will deploy and integrate multi-standard radio base stations, its RBS 6000, across the country, and a core network expansion including Evolved Packet Core (EPC) and Mobile Packet Backbone Network (MPBN) that will provide better mobile broadband connectivity and improve the capacity of Korek's network. [BMI, July 2012]

As a result of the slow progress, to date, Mobitel – which is based in the semi-autonomous Kurdistan Region of Iraq – holds the country's sole 3G cellular licence; Kurdistan boasts its own independent Ministry of Communications (MoC KRG), which takes responsibility for all licensing issues affecting the semi-autonomous zone. Elsewhere in Iraq the jamming of mobile phone frequencies by the military to prevent insurgents from detonating bombs remotely remains the most serious stumbling block. However, with near-neighbours such as Saudi Arabia and Kuwait deploying 4G LTE networks in late-2011 Iraq's trio of mobile operators are in danger of being left behind unless the MoC addresses its glaring regulatory deficiencies. [TeleGeography, 2012]

Table 3.2: Iraqi Providers and Technology used

Provider Name	Generation	Platform	Evolution	Frequency	Launch	Status	Network Details
							18 governorates)
Asiacell	2.5G	GSM	GPRS	900	Q4 2004	Live	Mar-12: 'National' (all 18 governates)
Asiacell	2.5G	GSM	EDGE	900	Q4 2008	Live	Mar-12: Unknown
Korek Telecom	2G	GSM	None	900	Aug 2001	Live	Mar-12: ~60% geographical coverage; Kurdistan and other parts of Iraq
Korek Telecom	2.5G	GSM	GPRS	900	May 2006	Live	Mar-12: ~60% geographical coverage; Kurdistan and other parts of Iraq
Mobitel (Kurdistan Region)	2G	GSM	None	900	Feb 2007	Live	Mar-12: Unknown (Kurdistan Region only)
Mobitel (Kurdistan Region)	3G	CDMA	None		Feb 2007	Live	Mar-12: Unknown (Kurdistan Region only)
Mobitel (Kurdistan Region)	3.5G	CDMA	None		Jul 2007		Mar-12: Unknown (Kurdistan Region only)
SanaTel	2G	GSM	None	900	Jun 2004	Live	Unknown; believed to be inactive. Previously: Sulaymaniyah province only
Zain Iraq (formerly MTC Atheer)	2G	GSM	None	900	Aug 2001	Live	Mar-12: 90% (est); more than 3,700 sites at end-2011
Zain Iraq (formerly MTC Atheer)	2.5G	GSM	GPRS	900	Mar 2004	Live	Mar-12: 90% (est); more than 3,700 sites at end-2011

3.16 Summary

In summary, telecommunication plays a vital role in rebuilding Iraq and that Iraq needs more communication (data in particular) especially in rural areas. The Internet connectivity is becoming a need as important as voice as it is vital to economic development and Wireless Broadband is the best solution as its deployment is rapid, flexible and inexpensive. Both 3G solutions (CDMA and WCDMA) are widely deployed around the world and the cost of terminals is declining rapidly and therefore represent the best solutions for Iraq also GSM Operators should deploy and provide 3G Services

The additional capacity being introduced by the submarines cables will increase the Penetration of broadband services in the enterprise and consumer segments and this additional capacity will result in a 50% reduction in prices. New services such as IPTV and rich media content will become available in Iraq with content providers such as the Al Jazeera and OSN and many others news or service providers are well placed to take advantage of the ability to reach a wide customers and audience.

Chapter Four

4.0 CDMA Performance Measurements and QoS.

4.1 Introduction

The Iraqi market's use of wireless communication increased dramatically and is still on the increase and the expected high demand has led many service providers (GSM, CDMA, WiMax and Wi-Fi) to not only investigate the QoS and performance of their networks to satisfy the increasing demand after so many problems with call drops, networks jamming, fading etc but also look at the coverage of a system and ways of improving it with the help of Physical as well as System Optimisation. This requires On Field Drive Test, Data Analysis, Physical changes & Parameter Optimisation.

Drive Testing (DT) is the best way to measure and analyse network QoS and Performance by means of coverage, system availability, network capacity and call quality. A drive test route was designed to cover the intended service area for investigation.

Using ZXPOS CNT (ZTE Drive Test Software for CDMA Network) and ZXPOS CNA(ZTE Analysis Software for CDMA Network) are tools for the DT to collect data for the measurements and analysis to provide useful recommendations for fixing or correcting the parameters for better performance (see Appendix D).

The geographical scope of these measurements covers: Centre of the capital city of Baghdad to investigate overall performance issues and also one BTS Site 2 (Dthubat) which suffers from bad QoS like call drops and signal fading according to customer complains. See Figure 4.11 Site 2 Dthubat Exchange.

Measurements also taken from all the major cities in Kurdistan region which have only NewrozTelecom (Reber) as an CDMA service Operator in all North of Iraq regions namely Erbeel (Appendix C), Dhouk (Appendix B), Zakho (Appendix A) and these will be incorporated in the appendices.

4.2 Network Performance Measurements

The Performance of a Network is based on two different criteria. One of them is Coverage and the second one Capacity.

The Coverage performance is based on different criteria, which include:
Mobile Receive Power (Rx), Mobile Transmit Power (Tx), Pilot Strength (Ec/Io), Forward Frame Error Rate (FER), Tx-Adj Distribution and BTS RSSI.

Rx: The Mobile Receive Power is the total power being received by the MS (Mobile Station) from all the BTS (Base Transceiver Station) around it. Mobile received power is one index to measure forward link coverage deepness.
MS received sensitivity is -105dBm, consider 5dB edge coverage margin, for different environments, the DT test measurements data should satisfy the following requirement:
In order for a good indoor coverage 85-90% of measurement bins should lie below -75dBm value for dense indoor coverage, for outdoor coverage Rx Power > -100dBm and normal indoor coverage Rx Power > -85dBm. [Huawie, 2003]

Tx: The Mobile Transmit Power is the power that MS radiates to the BTS. This is another index to measure the reverse link coverage deepness. The Tx power is 23dBm, considering 5dB edge coverage margin so the DT test should satisfy the following requirements: The Transmit power depends upon the Mobile Receive Power &**TxAdj** (Power Control) which reflects closed-loop power control adjustment. [Sinau online, 2013]

Tx Power < 18 dBm is the range for outdoor coverage;
Tx Power < 3dBm is the range for indoor coverage;
Tx Power < -2dBm is the range for dense indoor coverage;

Ec/Io: This is the received Pilot Strength of Dominant PN (Pseudo Noise) with respect to total power received (which appears to be interference to the decoded PN). This ranges from (0 to -13dBm).
Ec: This is the signal strength measurement of the pilot expressed in dBm units. For example, the pilot signal may have an Ec value of -50 dBm, -80 dBm,
or -100 dBm, depending on where the drive-test equipment is located with respect to the base station transmitting that pilot signal.

Ec/Io is third important index to measure forward link coverage performance. Usually the cell threshold is >-15dB. In order to guarantee reliable demodulation, the maximum pilot threshold need >-13dB. Pilot power ratio usually can not be changed. [Agilent, 2000]

Io: This is a measure of the total power (dBm) within the 1.25 MHz bandwidth channel. Ec/Io is the power in an individual base station pilot divided by the total power in the 1.25 MHz channel, expressed in dB. It provides a useful ratio to compare the power levels of the base stations with respect to one another.

FER (Frame Error Rate): This is the factor which indicates the quality of voice of the system. The FER value should be below 2% threshold. In CDMA system, the ideal objective FER is about 1% for 8K voice service. For voice service, FER increase will lead to bad voice quality. In coverage edge area, because of bad signal, FER may be high.

4.3 Network Performance Measurements Test.

4.3.1 Overview

Baghdad is the capital of Iraq and Located in the centre of Iraq. The population of Baghdad in 2011 is approximately 7,216,040. It is the largest city in Iraq, the second largest city in the Arab World (after Cairo, Egypt), and the second largest city in Western Asia (after Tehran, Iran). It has a total area 2,260.2 km^2 (872.7 sq mi).

4.3.2 Drive Test

During the Drive Test (DT), the test terminal moves along the chosen routes and records various test data of different test points. According to the test content, DT can be divided into Continuous Call and Periodical Call.

4.3.3 DT Routes

The voice service DT routes are selected with the approval of ITPC as Operator and ZTE as equipment vendor, and obtained the agreement of both sides.

The voice service DT routes are shown in the following figure:

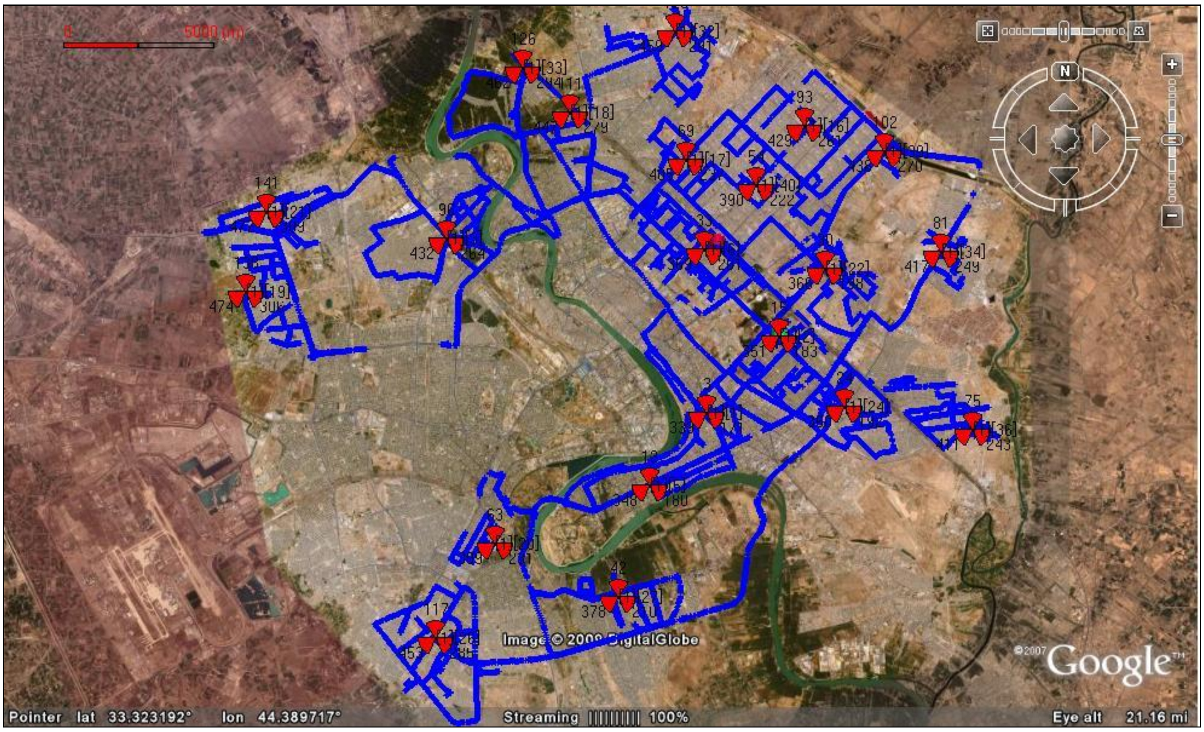


Figure 4.1: Voice Service DT Routes in Baghdad

The above Figure 4.1 show the routes taken for the DT and data collected from these BTS for analysis. These areas cover about 20 Base Transceiver Stations (BTSs) that account for almost half of all Baghdad coverage and are located in the most populated areas.

4.4 Devices Used in the Drive Test

1. Test terminal.
2. Direct test cable.
3. Laptop.
4. Power inverter, socket.
5. GPS and data cable.
6. ZXPOS CNT1: ZTE Drive Test Software for CDMA network.
7. ZXPOS CNA1: ZTE Analysis Software for CDMA network.
8. MapInfo digital maps.
9. Data card, cable.

10. Vehicle

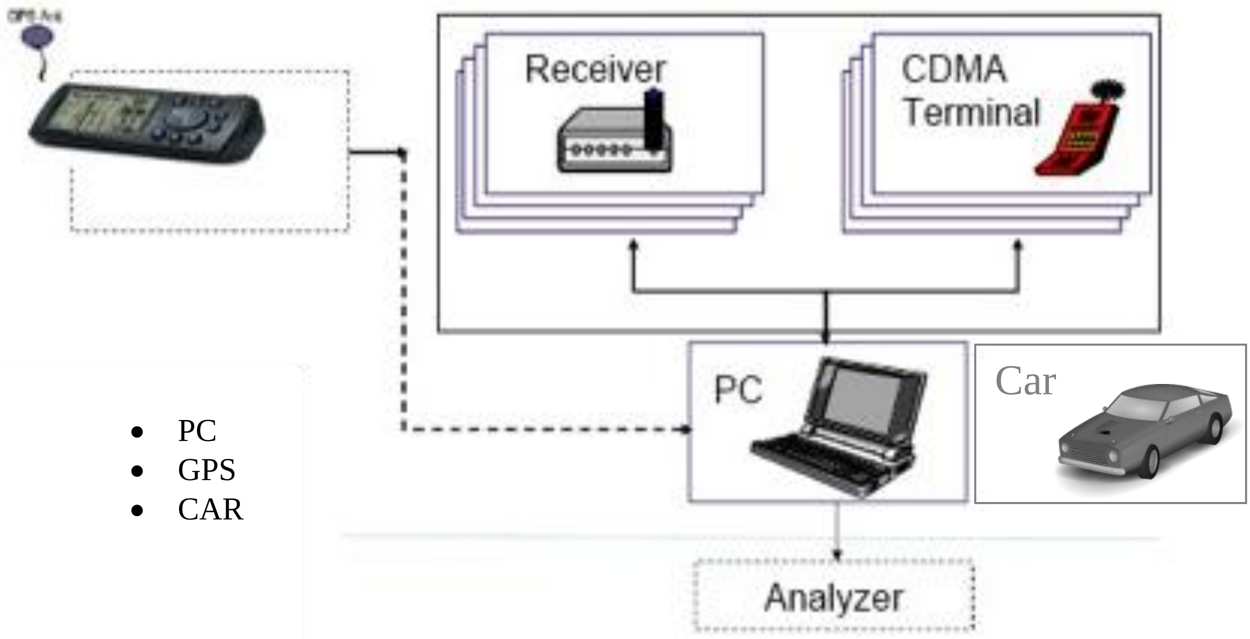


Figure 4.2: Drive test configurations

4.5 Drive Test Results

4.5.1 Forward Received Power

Rx indicates the intensity of the forward signal. The Quality of a CDMA system is related to the signal intensity and the signal quality, so when measuring the system’s forward coverage, it is needed to combine the Forward Received Power along with the pilot Ec/Io.

The DT data was judged to determine whether the coverage requirements can be satisfied. It is necessary to leave proper margin for penetration for buildings and other clutter and margins for the signal fading i.e. about 5dBm.

Forward Received Power Rx（dBm）	Legend Colour	Description
Rx ≤ -105	Black	The coverage is very poor and the service areas can not get coverage.
-105 < Rx ≤ -95	Red	The coverage is poor and can not guarantee the outdoor coverage.
-95 < Rx ≤ -85	Yellow	The coverage is common and can not guarantee the indoor coverage.
-85 < Rx ≤ -75	Green	The coverage is relatively good and can guarantee the indoor coverage generally.
-75<Rx <-65	Blue	The coverage is good.
Rx >-65	Sky blue	The coverage is very good.

Table 4.1: Legend of Forward Received Power

The Mobile Receiver power (RX) i.e. the received power at handset (Mobile)(dBm). The received power important but the exact value not critical.

High RX value > -65 give very good coverage and voice quality but not as low as -35dBm as this could cause overload condition in amplifier sensitivity.

Lower Rx value <-105 dBm or weaker would leave too much noise in the signal after dispreading resulting in very poor coverage.

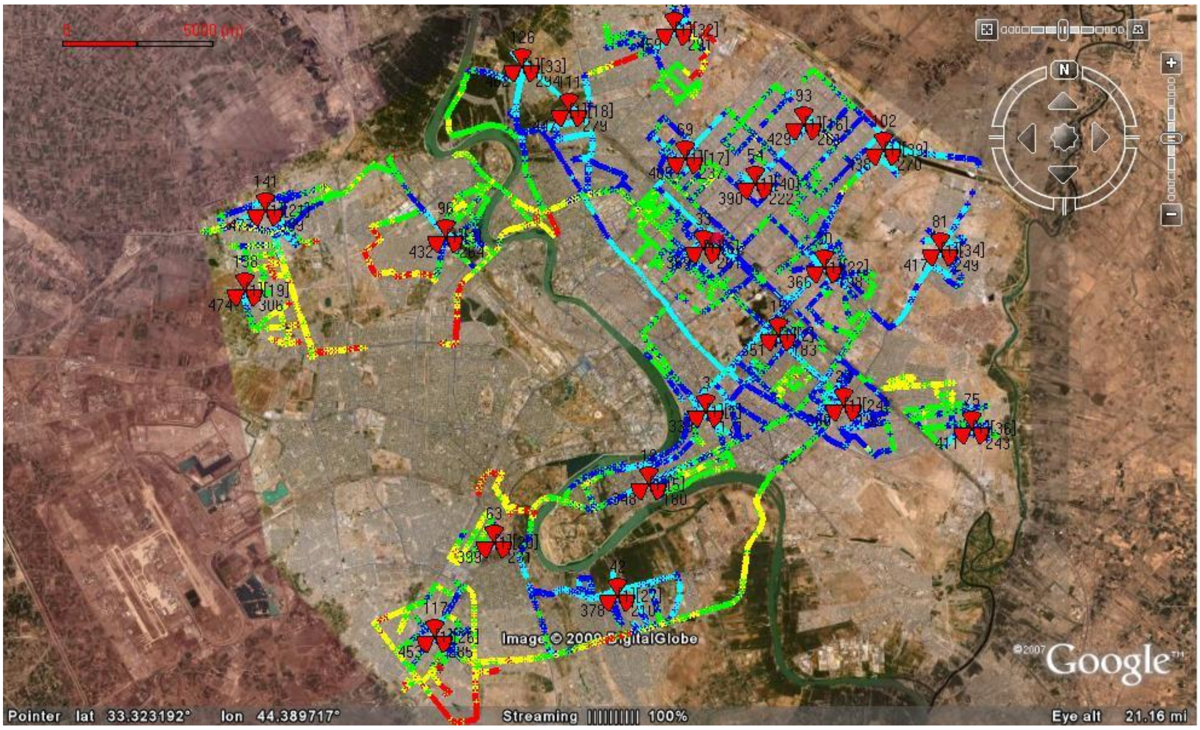


Figure 4.3: Forward Received Power of Network in DT

The above Figure 4.3 shows Drive test routes with different values of forwards received power (RX) with different colour with some areas coverage performance.

Table 4.2: Forward Received Power Distribution

Category	**(+INF, -65)**	**[-65, -75)**	**[-75, -85)**	**[-85, -95)**	**[-95, -105)**	**[-105, -INF)**
Percentage	24.12	31.18	28.31	13.18	3.21	0
Count	64721	83658	75958	35373	8615	13
Cumulative Percentage	24.12	55.3	83.61	96.79	100	100
Cumulative Count	64721	148379	224337	259710	268325	268338

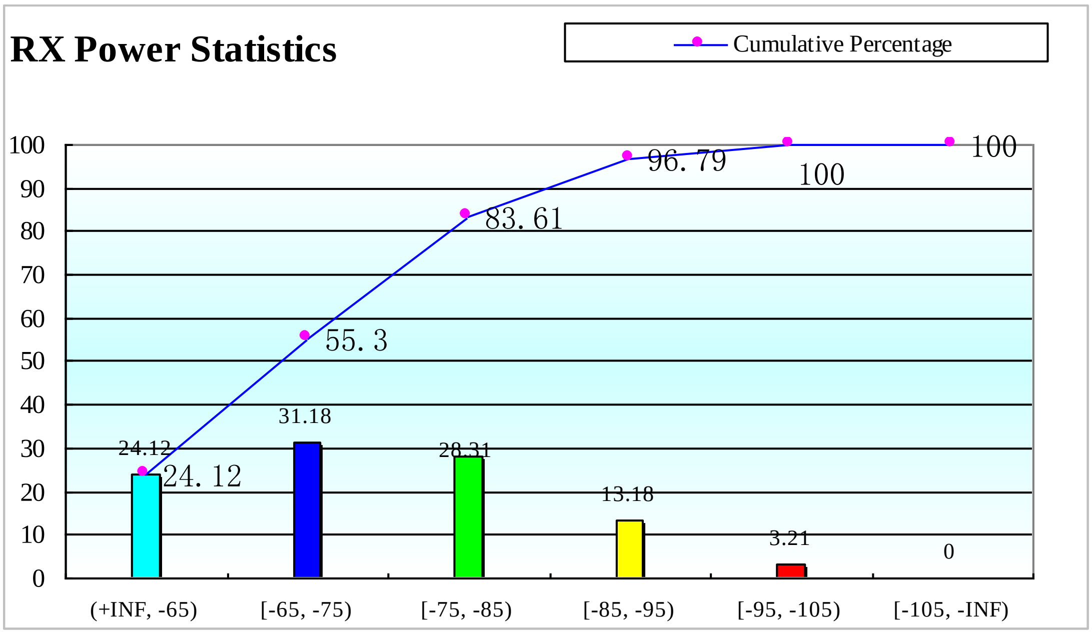


Figure 4.4: Forward Received Power Distribution

The above table 4.2 and figure 4.4 shows that there only 55% of areas have good voice quality and almost 16% quality poor and can not be guaranteed.

4.5.2 Aggregate Ec/Io

Ec/Io indicates the quality of the forward signal. This parameter has a great influence on the quality of the voice service.

The received Pilot Strength of Dominant PN with respect to total power received is a measure of interference to the decoded PN. This ranges from (0 to -13dBm). Ec/Io is a parameter, which represents pilot cleanness and is derived from the ratio of good to bad energy. The good energy can be degraded by strong RF from other cell sectors and could cause -20 dB degradation and can also be degraded by noise.

So Io is the sum of the energies of all the signals received by MS, and Ec is the energy of desired sector’s pilot signal. The large Io will override the weak Ec.

Ec/Io is the ratio of energy per chip to the interference power spectral density. It is equivalent to thinking of these terms—Ec and Io—as the ratio of power.

Forward Ec/Io (dB)	Legend Colour	Description
Ec/Io ≤ -15	Black	The coverage is very poor and can hardly be achieved.
-15 < Ec/Io ≤ -12	Red	The coverage is relatively poor. The rate of data service is low, and the quality of the conversation can not be guaranteed.
-12 < Ec/Io ≤ -10	Yellow	The coverage of voice service is common, and the rate of data service can not be guaranteed.
-10 < Ec/Io ≤ -8	Green	The coverage of the voice service is relatively good, and the data service can generally reach a relatively higher rate.
-8<Ec/Io ≤-6	Blue	The coverage is good.
Ec/Io > -6	Sky Blue	The coverage is very good.

Table 4.3: Legend of Aggregate Ec/Io

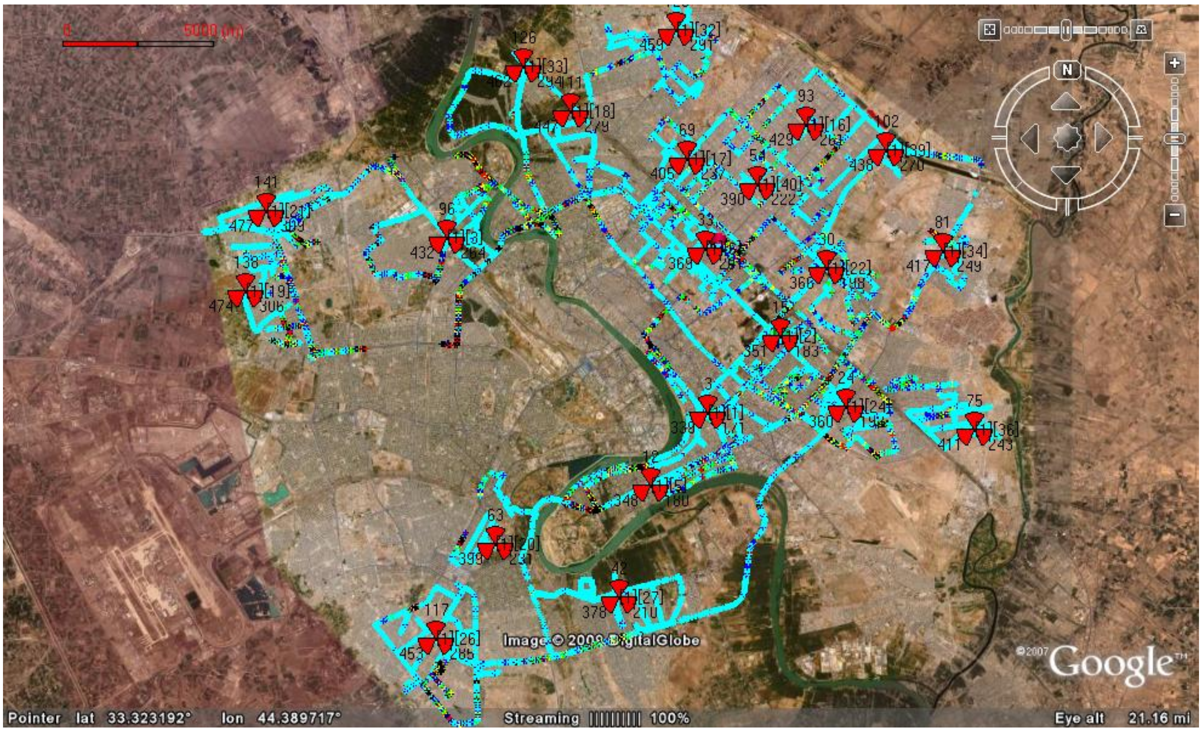


Figure 4.5: Aggregate Ec/Io of Network in DT

The above route in Figure 4.5 used for the Drive test with Ec/Io result which show the BTS and signal strength. The value of Ec/Io varies. If the value starts to get too low, you start to have dropped calls, or cannot connect.

Table 4.4: Aggregate Ec/Io Distribution

Category	**(+INF, -6)**	**[-6, -8)**	**[-8, -10)**	**[-10, -12)**	**[-12, -15)**	**[-15, -INF)**
Percentage	77.08	8.52	4.64	2.74	2.63	4.39
Count	169345	18724	10198	6015	5788	9649
Cumulative Percentage	77.08	85.6	90.24	92.98	95.61	100
Cumulative Count	169345	188069	198267	204282	210070	219719

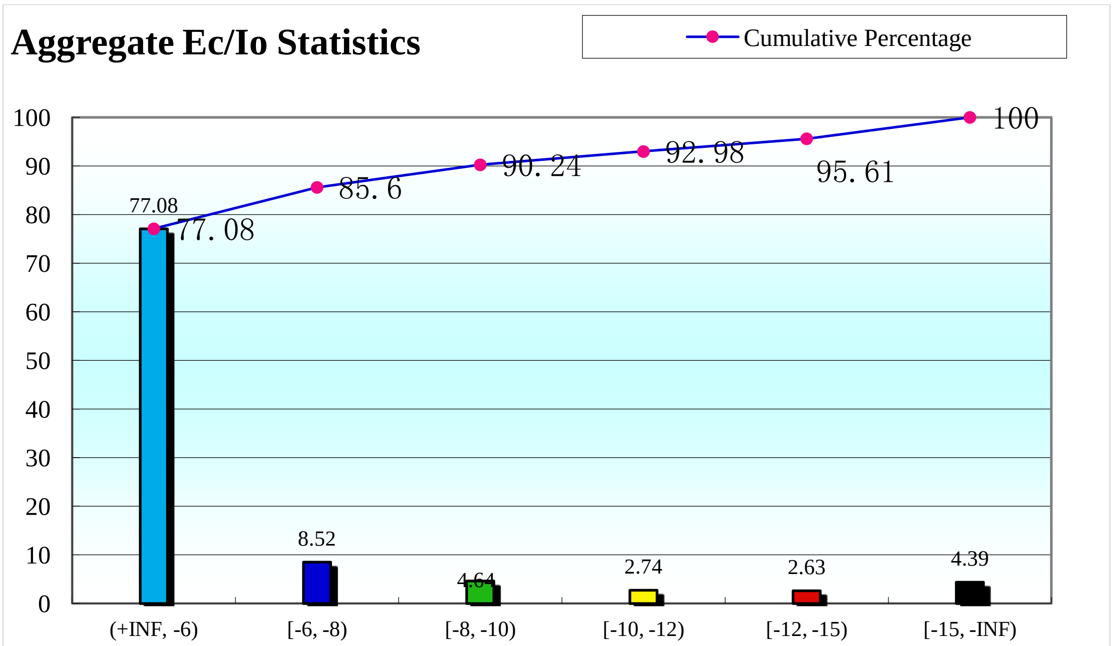


Figure 4.6: Aggregate Ec/Io Distribution

The Table 4.4 and Figure 4.6 show the value of Ec/Io below - 10 db for 85% of measured regions which is a reasonable value to consider as good.

Also in the above situations where Ec/Io is very low (i.e. below -15db) and the signal level is also a high negative number, first we need to be concerned about enhancing the weak signal.

To have good signal and quality we need to maintain the Ec/Io value to be higher than -6db and not below -10db.

4.5 3 Reverse Transmit Power

TX reflects the reverse (return channel) coverage performance.

Reverse Tx (dBm)	Legend colour	Description
Tx > 23	Black	The coverage is very poor and can hardly be guaranteed.
13 < Tx ≤ 23	Red	The coverage is relatively poor, and the outdoor coverage cannot be guaranteed.
3< Tx ≤ 13	Yellow	The coverage quality is common, and the indoor coverage cannot be guaranteed.
–10< Tx ≤ 3	Green	The coverage is relatively good, and the indoor coverage can generally be guaranteed.
-20<Tx ≤-10	Blue	The coverage quality is good.
Tx ≤–20	Sky Blue	The coverage quality is very good.

Table 4.5: Legend of TX

CDMA (Code Division Multiplexing Access) combines multiple new techniques, including forward and reverse power control, soft handoff or handover, and diversity.

There are forward and reverse power controls for both upstream and downstream links for CDMA Mobile Communication System of ZTE. The forward power control assigns reasonable power with all forward channels to ensure accepted quality of service. [ZTE, 2003]

Mobile Station transmitting power is very important to measure reverse link coverage. MS maximum Tx power is 23dBm, which gives a very poor coverage, see Table 30. If we consider a 5dB edge coverage margin, for different environment, DT test data should satisfy the following requirement: Tx Power < 18dBm is the range for outdoor coverage and cannot be guaranteed; Tx Power < 3dBm is the range for indoor coverage; Tx Power < -2dBm is the range for dense indoor coverage up to -20dBm.

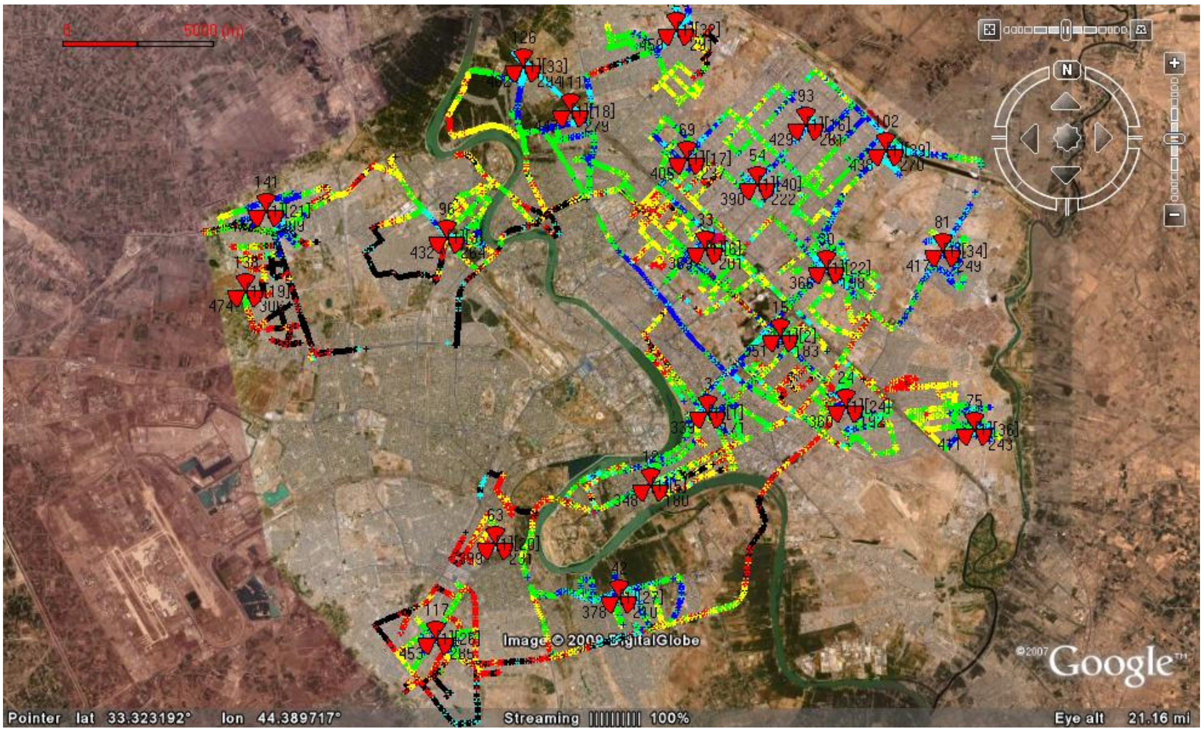


Figure 4.7: TX of Network in DT

The above Figure 4.7 shows the routes and values taken for the measurements and clearly indicate there is an issue with the TX Power in many areas of the capital Baghdad.

Table 4.6: Reverse Transmit Power Distribution

Category	(-INF, -20]	(-20, -10]	(-10, 3]	(3, 13]	(13, 23]	(23, +INF)
Percentage	12.37	15.75	31.18	19.71	12.62	8.37
Count	27108	34514	68289	43193	27657	18341
Cumulative Percentage	12.37	28.12	59.3	79.01	91.63	100
Cumulative Count	27108	61622	129911	173104	200761	219102

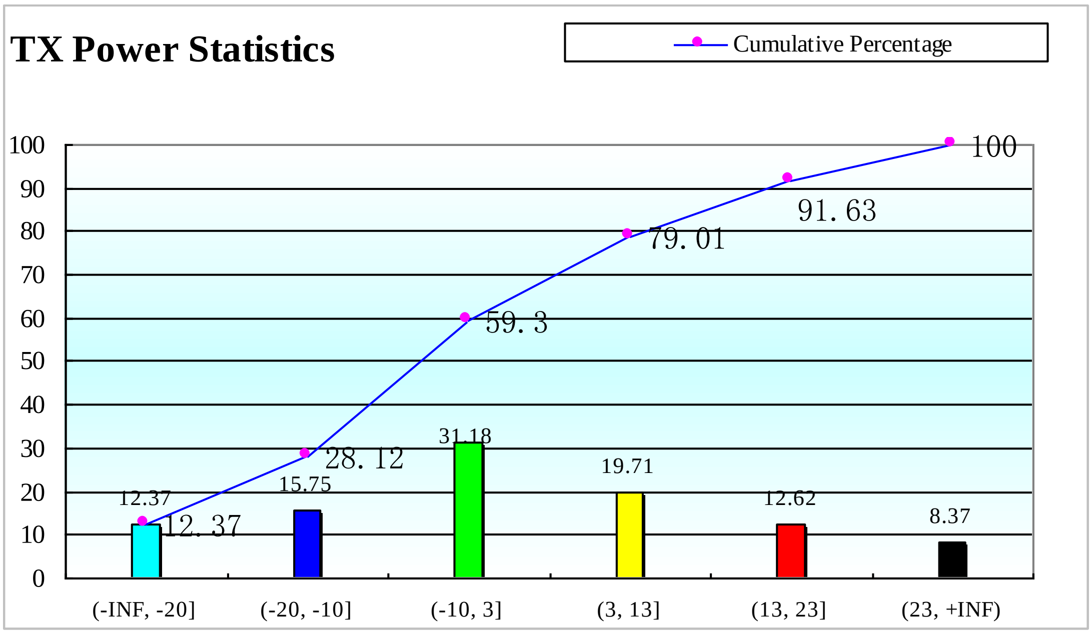


Figure 4.8: Reverse Transmit Power Distribution

The above Table 4.6 and Figure 4.8 clearly indicate there is almost 40% of the area cannot guarantee voice quality, only 59% have acceptable quality, also over 20% have poor coverage and even outdoor coverage can not be guaranteed.

4.5.4 F-FER

The forward FER characterizes the quality of basic channels in voice service.

Forward FER (%)	Legend Colour	Description
FFER > 5	Black	The voice quality is very poor.
3 < FFER ≤ 5	Red	The voice quality is relatively poor and subscribers can detect this easily.
2 < FFER ≤ 3	Yellow	The voice quality is common. Subscribers can detect no obvious voice defects.
1 < FFER ≤ 2	Green	The voice quality is relatively good, and subscribers can hardly feel voice defects.
FFER ≤ 1	Blue	The voice quality is good.

Table 4.7: Legend of Forward FER

Forward FER (Frame Error rate) reflects forward link coverage integrated quality. In CDMA system, the ideal value for FER is about 1% for 8K voice service. For voice service, a FER increase will lead to bad voice quality. In coverage edge areas, because of bad signal, FER may be high not more than 3. FER values above 3 result in poor quality of service.

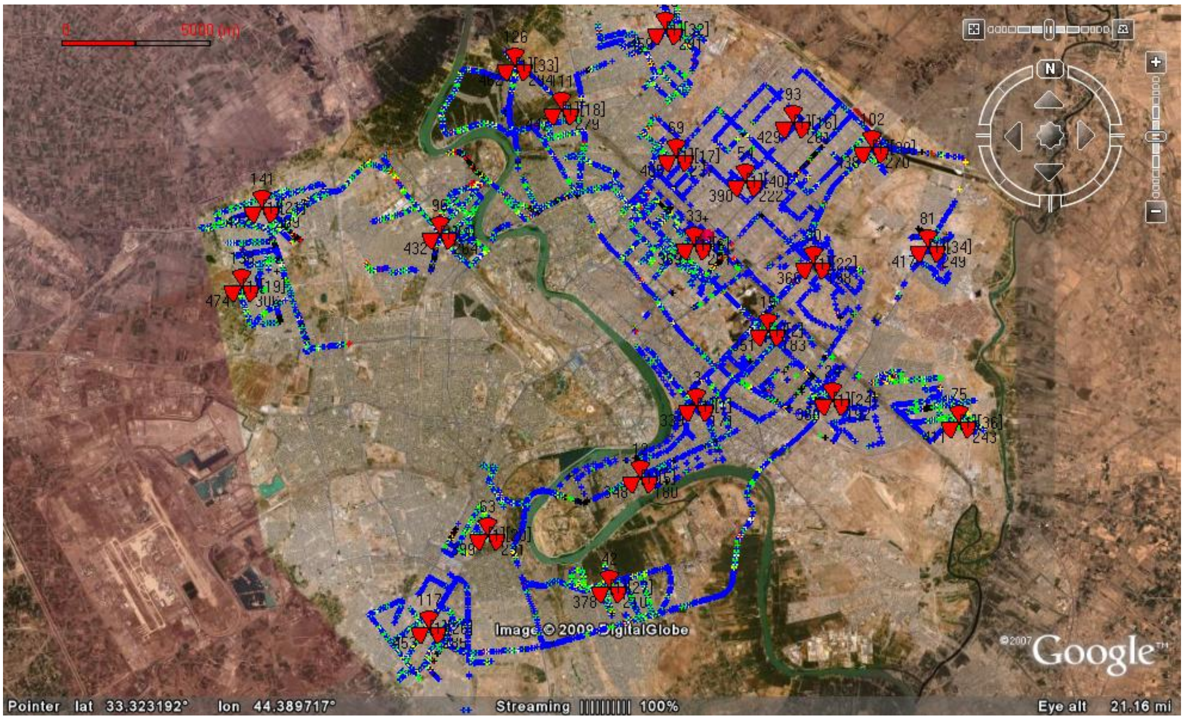


Figure 4.9: Forward FER of Network in DT

The above figure 4.9 show the routes used by the Drive Test and measurements taken for the forwards FER in the centre of Baghdad for the 20 BTS.

Table 4.8: Forward FER Distribution

Category	**(-INF, 1]**	**(1, 2]**	**(2, 3]**	**(3, 5]**	**(5, +INF)**
Percentage	67.42	22.41	5.89	1.51	2.77
Count	119370	39682	10422	2674	4897
Cumulative Percentage	67.42	89.83	95.72	97.23	100
Cumulative Count	119370	159052	169474	172148	177045

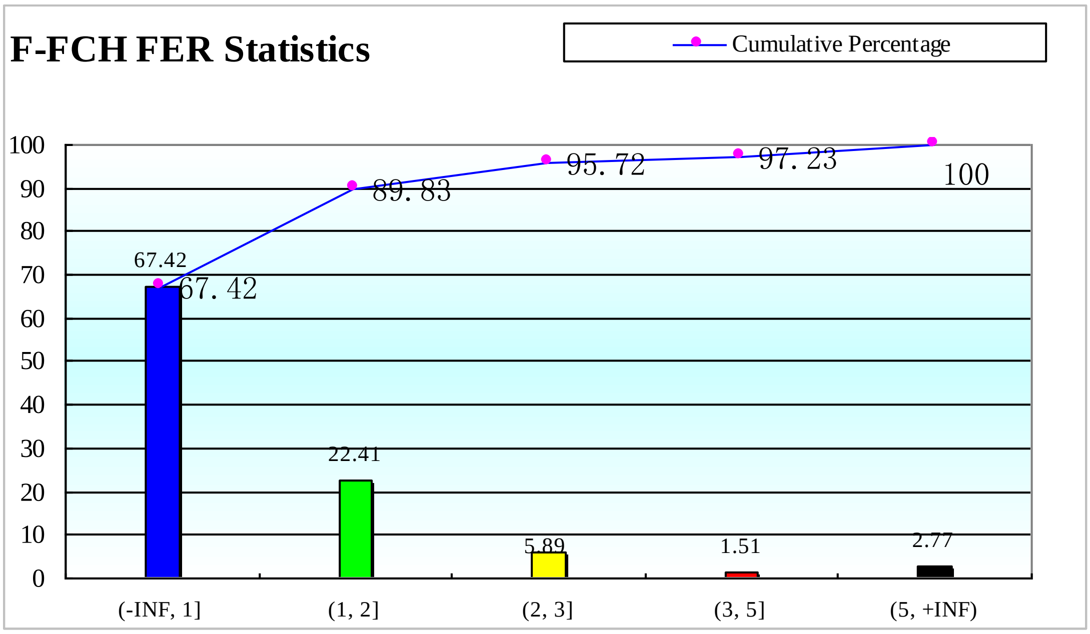


Figure 4.10: Forward FER Distribution

The table 4.8 and Figure 4.10 show only 67% of the subscribers have good very good voice quality and another 22.4% with relatively good service but still about 10% suffer from poor voice quality.

4.5.5 Tx-Adj Distribution

Tx_Adj reflects closed-loop power control adjustment. Usually, Tx_Adj range should be 0 to -10dBm. Too high or too low Tx_Adj values are all abnormal phenomena and indicate that the forward and reverse link are not balanceable. Too low Tx_Adj indicates reverse link is better than forward link, or reverse link initial power is too high; too high Tx_Adj indicates forward link is better than reverse link, or that there is reverse interference. The best value when the Tx-Adj value Tx_Adj≤ -10 and radio environment bad when the 5 < Tx_Adj≤ 10. See Table 4.11, which shows Tx_Adj values.

Table 4.9: Legend of Tx-Adj Distribution

Forward FER (%)	Legend Colour	Description
Tx_Adj$>$ 10	Black	The radio environment is very bad in reverse link.
5 $<$ Tx_Adj$\leq$ 10	Red	The radio environment is relatively bad in reverse link.
0 $<$ Tx_Adj$\leq$ 5	Yellow	The radio environment is common inreverse link.
0 $<$Tx_Adj$\leq$ -10	Green	The radio environment is relatively good in reverse link.
Tx_Adj$\leq$ -10	Blue	The radio environment is good inreverse link.

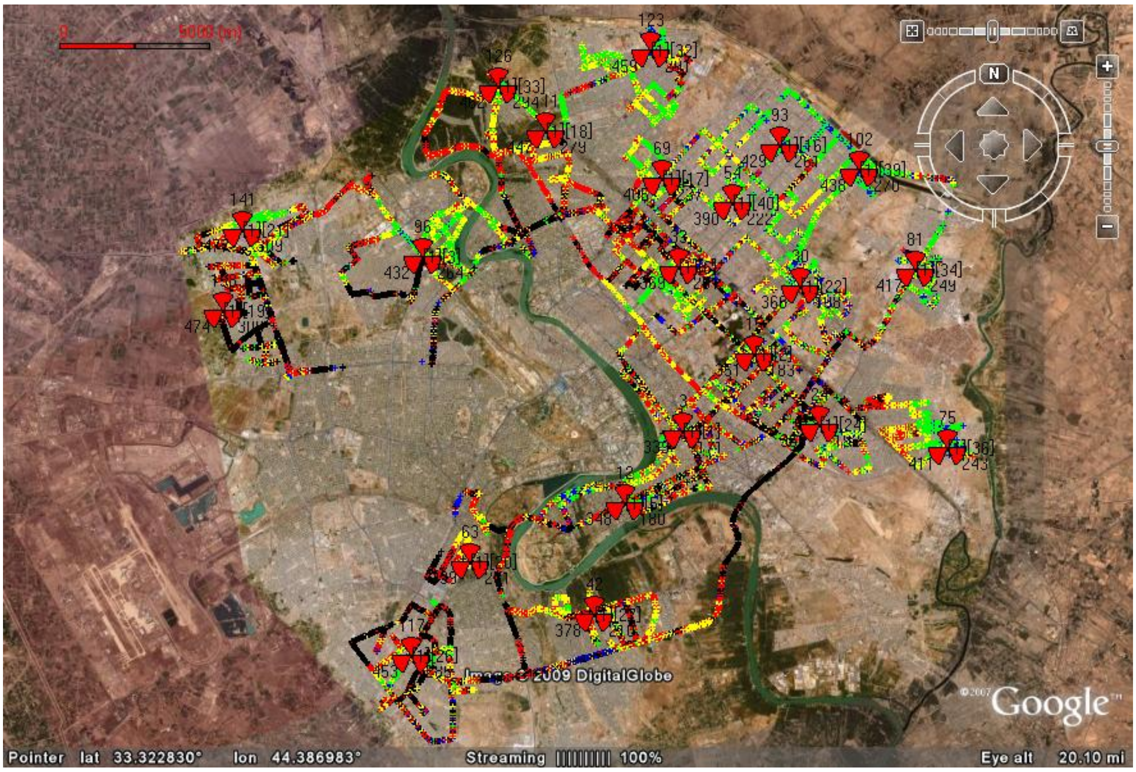


Figure 4.11: Tx-Adj Distribution of Network in DT

Figure 4.11 shows the routes taken for the Drive Test (DT) and measurements collected for the Tx_adj in all the 20 BTS in central Baghdad. The red and black colours indicate the bad radio environment in reverse link.

Table 4.10: Tx-Adj Distribution

Category	(-INF, -10]	(-10, 0]	(0, 5]	(5, 10]	(10, +INF)
Percentage	4.83	24.66	25.22	23.27	22.02
Count	10581	54033	55268	50979	48241
Cumulative Percentage	4.83	29.49	54.71	77.98	100
Cumulative Count	10581	64614	119882	170861	219102

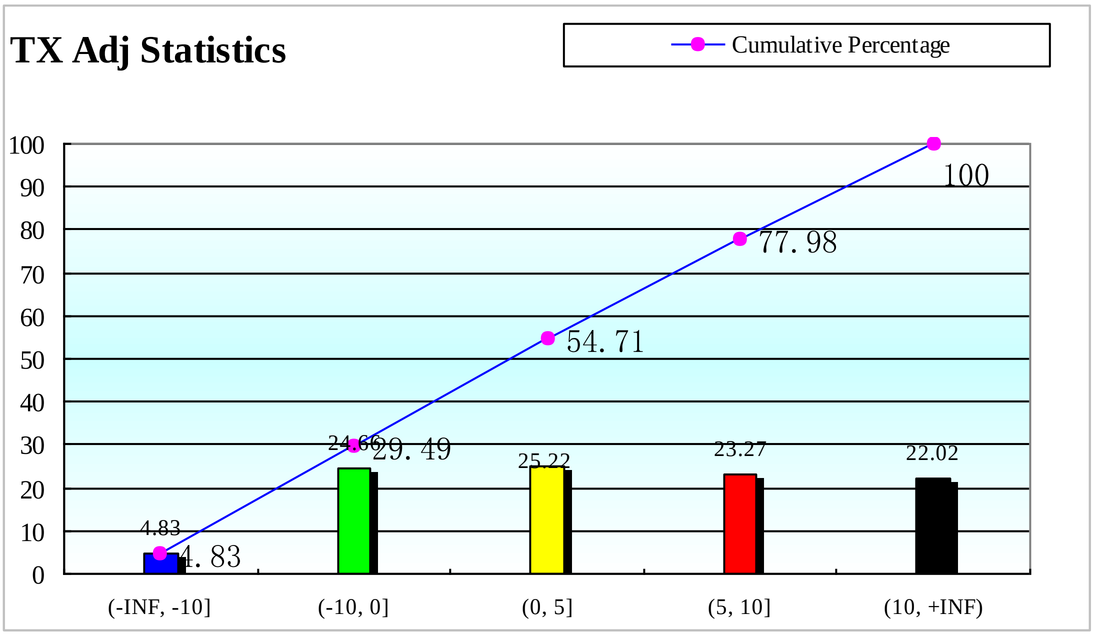


Figure 4.12: Tx-Adj Distribution

Tx_Adj reflects closed-loop power control adjustment. Usually, Tx_Adj range should between 0 to 10dBm. Too high or too low Tx_Adj value are all abnormal and indicate forward and reverse link are not balanceable. The above table 4.10 and Figure 4.12 shows there is a major issue with the radio environments with almost 35% too low so Tx_Adj indicating the reverse link is better than forward link, or reverse link initial power is too high; also 28% shows too high Tx_Adj which indicates forward link is better than reverse link, or there is reverse interference. [Sinau online, 2013]

4.5.5 BTS RSSI (Received Signal Strength Indication)

BTS RSSI indicates received signal strength in reverse link.

The received signal strength indicator is measured in dBm of both the mobile unit and the base station within a wireless environment. RSSI value is used to initiate a power change or handoff but does not necessarily indicate signal quality.

The RSSI is more than the normal threshold -85dBm; we propose to check whether interference occurs in reverse link. See table 4.11, which have the RSSI for all sites in central Baghdad with measurement of the RSSI.

Table 4.11: Exceptional RSSI statistics

BTS No.	BTS Name	Cell	Avg Main RSSI(dBm)	Avg Diversity RSSI(dBm)
1	Alwiya Exchange	1	-90.96	-85.84
1	Alwiya Exchange	2	-86.1	-86.4
1	Alwiya Exchange	3	-89.93	-88.29
2	dthubat exchange	1	-92.04	-91.78
2	dthubat exchange	2	-88.84	-84.29
2	dthubat exchange	3	-88.95	-89.36
3	kadthimiya exchange	1	-91.58	-94.15
3	kadthimiya exchange	2	-88.98	-90.43
3	kadthimiya exchange	3	-89.23	-91.04
5	jadiriya exchange	1	-88.9	-90.12
5	jadiriya exchange	2	-91.33	-91.98
5	jadiriya exchange	3	-86.86	-86.15
6	idreesi site	1	-92.24	-92.95
6	idreesi site	2	-89.21	-88.07
6	idreesi site	3	-93.81	-94.01
16	fida exchange	1	-93	-96.31
16	fida exchange	2	-91.13	-89.62
16	fida exchange	3	-91.32	-92.84
17	14th July exchange	1	-96.95	-97.16
17	14th July exchange	2	-89.75	-92.22
17	14th July exchange	3	-91.84	-87.21
18	sababkar exchange	1	-93.64	-95.76
18	sababkar exchange	2	-93.95	-92.35
18	sababkar exchange	3	-92.66	-93.68
19	gazaliya exchange	1	-93.65	-92.62
19	gazaliya exchange	2	-83.38	-84.1
19	gazaliya exchange	3	-85.83	-84.57
20	bayaa microwave	1	-92.76	-108.75
20	bayaa microwave	2	-89.19	-92.44
20	bayaa microwave	3	-90.74	-91.65
21	shula exchange	1	-89.77	-91.17
21	shula exchange	2	-85.58	-85.75
21	shula exchange	3	-88.91	-92.25
22	habeebiya site	1	-92.83	-96.84
22	habeebiya site	2	-87.27	-89.57
22	habeebiya site	3	-84.96	-84.45
24	new Baghdad exchange	1	-87.3	-89.4
24	new Baghdad exchange	2	-77.79	-79.99
24	new Baghdad exchange	3	-79.54	-79.49
26	intisar exchange	1	-90.89	-92.4
26	intisar exchange	2	-93.53	-93
26	intisar exchange	3	-93.54	-89.96
27	dora exchange	1	-87.68	-89.65
27	dora exchange	2	-91.37	-90.07
27	dora exchange	3	-91.78	-94.54
32	alshuroofi site	1	-97.21	-95.17
32	alshuroofi site	2	-96.54	-99.64
32	alshuroofi site	3	-98.78	-99.97
33	sababkar microwave	1	-93.99	-96.21
33	sababkar microwave	2	-96.39	-95.57
33	sababkar microwave	3	-93.59	-96.35
36	Shamaiya site	1	-92.37	-92.47
36	Shamaiya site	2	-91.61	-92.01
36	Shamaiya site	3	-92.64	-94.78
40	diffa madani	1	-84.84	-86.6
40	diffa madani	2	-89.04	-88.72

RSSI can be used internally to determine when the amount of radio energy in the channel is below a certain threshold at which point the network card can send alerts and once the alerts have been sent then the engineer or device user can observe an RSSI value when measuring the signal strength of a wireless network through the use of a wireless network monitoring tool like ZXPOS or TEMS etc.

If the difference between main RSSI and diversity RSSI is over 6db then it may be caused by heavy traffic, antenna installation problems, faulty hardware or external interference. See BTS number 20 Bayaa microwave cell 1 in Table 4.13.

When RSSI is too high (i.e. over -95dBm) for long period of time or within certain period of time then the possible causes are switch and jumper errors, hardware fault and water penetration in connectors. See Table 4.11 BTS No 17, 32 and 33.

4.6 Baghdad Site 2

4.6.1 Overview

This section evaluates the network's quality and performance in one of the BTS CDMA service areas in Baghdad. Site 2 is selected for drive testing to measure and evaluate the performance and quality of service objectively. This site was selected from the customer's perspective as it has performance issues. On the basis of the network's actual conditions, the site was looked at from signal quality and a solution was recommended to solve the existing problems.

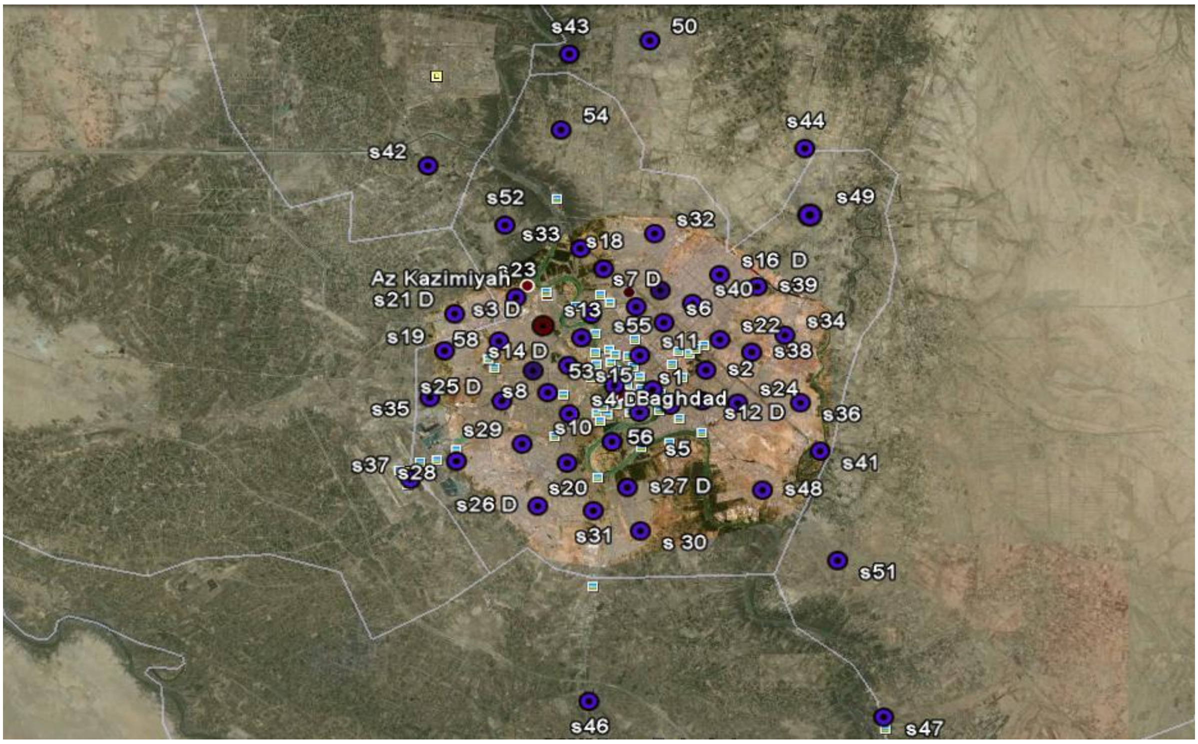


Figure 4.13: Baghdad BTS Distributions

The above Figure 4.13 shows all ITPC CDMA BTS in the centre of Baghdad area and surrounding areas.

Figure 4.14: Site 2 location in Baghdad.

The above figure 4.14 shows site two locations in Baghdad

DT (drive test) is the method used on specific route of the coverage area and records the performance data and position.

4.6.2 DT Test Routes

The voice and Data service Drive Test routes are selected with the approval of ITPC Engineers and ZTE as vendor and agree to test and collect data measurements to investigate the performance and QoS. The routes were selected carefully with neighbouring BTS and agreed the routes as shown in Figure 4.16.

Using Drive Test analysing software ZXPOS to analyse the data, judge for network quality in coverage area, and propose solution or recommendations to improve the service. DT software processing shows where the coverage quality is good and where the coverage quality is bad, and it is very clear by recording the real signal state and real transmission for all the events (origination, handoff, drop calls) what recommendations should be made to optimise the network and improve the experience the subscriber feeling since direct information can be obtained to locate the problems.

Figure 4.15: Site 2 Drive Test routes

4.6.3 Voice and Data DT Test Measurements Parameters

The voice measurements test parameters include:

1. 1. Forward Received Power

2. 2. Reverse Transmit Power

3. 3. Aggregate Ec/Io
4. 4. FFER
5. 5. Tx_Adj distribution

The CDMA systems parameters above should be used and analysis by operators periodically to optimise their networks to accommodate traffic growth and performance degradation. The basic objectives of this measurement are to ensure that the radio parameters for voice and data are maintained at their standard thresholds to enhance the network performance.

4.7 Drive Test Results

4.7.1 Forward Received Power

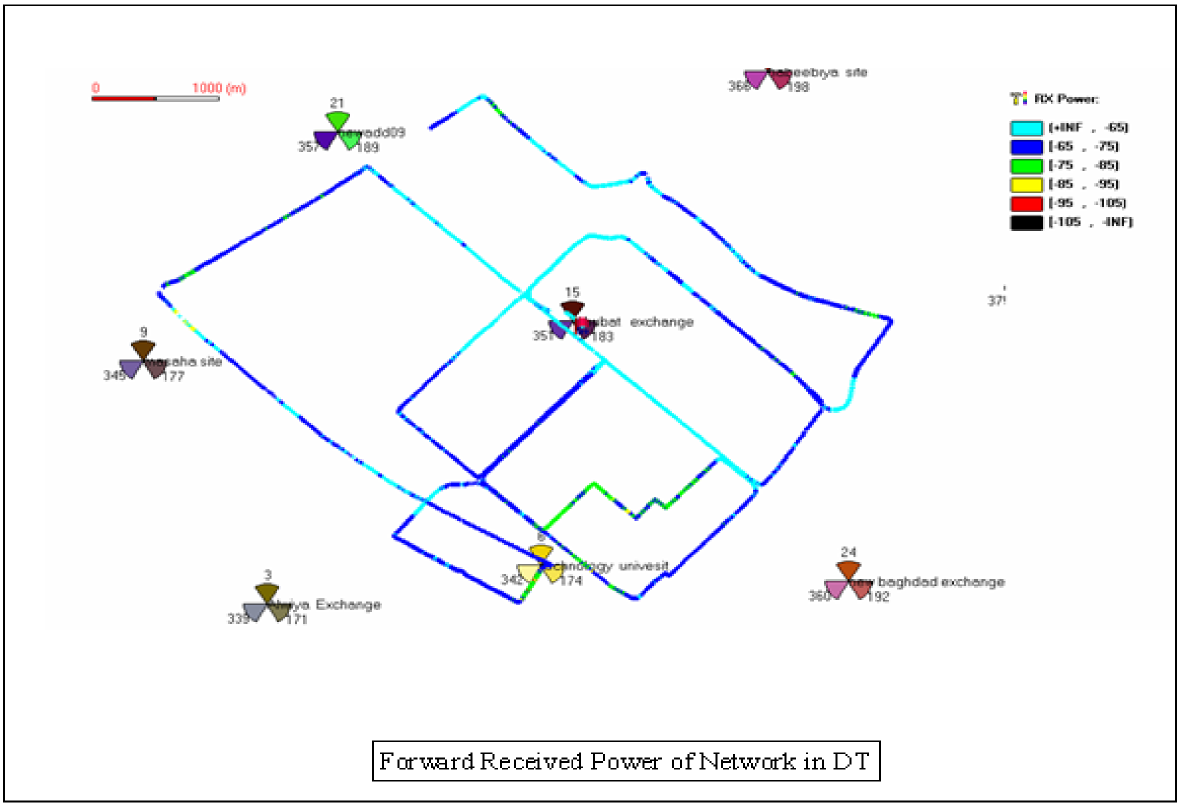


Figure 4.16: Forward Received Power Route

The above Figure 4.16 show the routes used for the driving test to collect data measurements for the Forward Received Power.

Table 4.12: Forwards Received Power

Category	[+inf, -65]	[-65, -75]	[-75, -85)	[-85, -95)	[-95, -105)	[-105, -INF)
Percentage	30.56	54.49	14.37	0.56	0.03	0
Count	6716	1711	1713	67	4	0
Cumulative Percentage	30.56	85.01	99.41	99.97	100	100
Cumulative Count	8427	10137	11848	11915	11919	11919

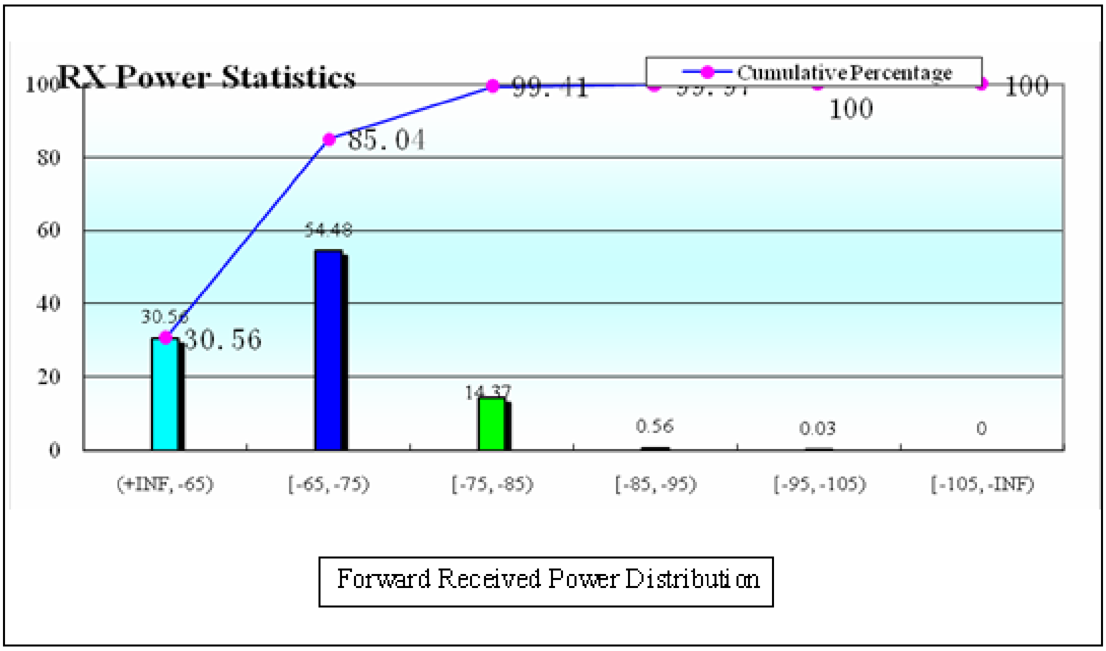


Figure 4.17: forward received power distribution

The above table 4.12 and Figure 4.17 show 99% percentage of the received power was acceptable with good coverage. Value of Rx > -85dBm is acceptable and when increased to Rx>-65dBm, which is very good coverage.

4.7.2 Aggregate Ec/Io

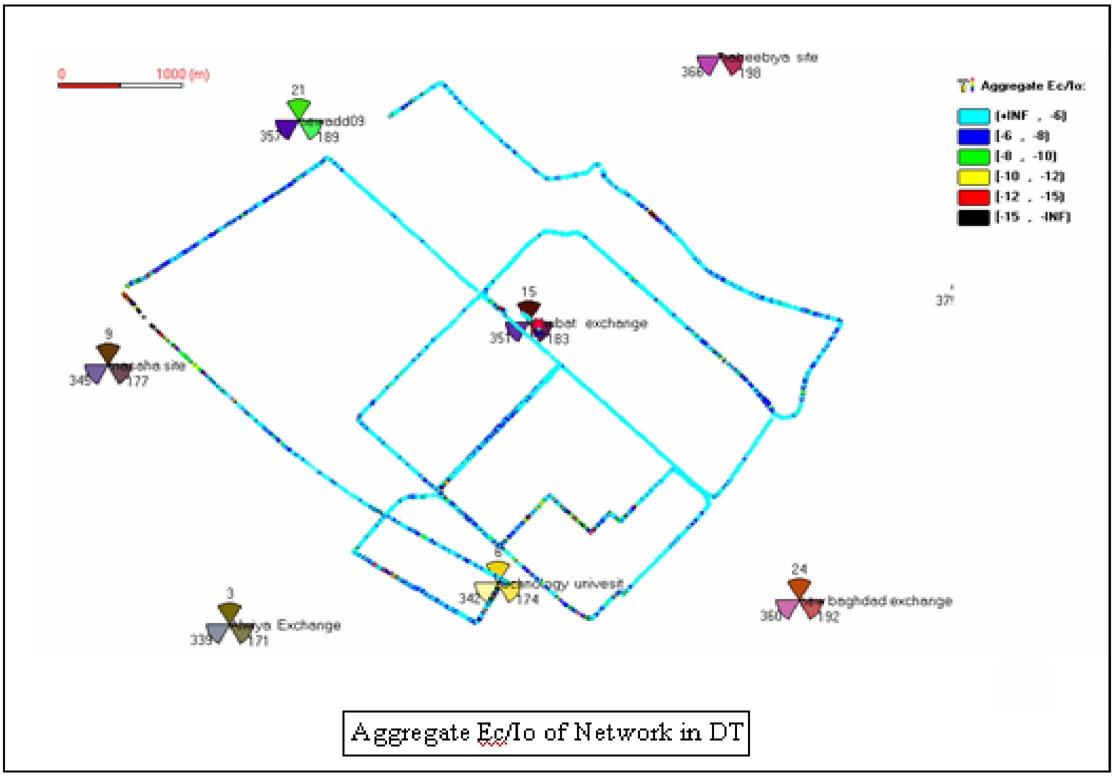


Figure 4.18: Aggregate Ec/Io DT measurements

The above Figure 4.18 shows that the routes and measurements taken for the Ec/Io for BTS site 2 in Baghdad.

Table 4.13: Aggregate Ec/Io Distribution

Category	(+INF, -6)	[-6, -8)	[-8, -10)	[-10, -12)	[-12, -15)	[-15, -INF)
Percentage	65.9	21.01	5.29	2.01	1.82	3.97
Count	6898	2199	554	210	191	416
Cumulative Percentage	65.9	86.91	92.2	94.21	96.03	100
Cumulative Count	6898	9097	9651	9861	10052	10468

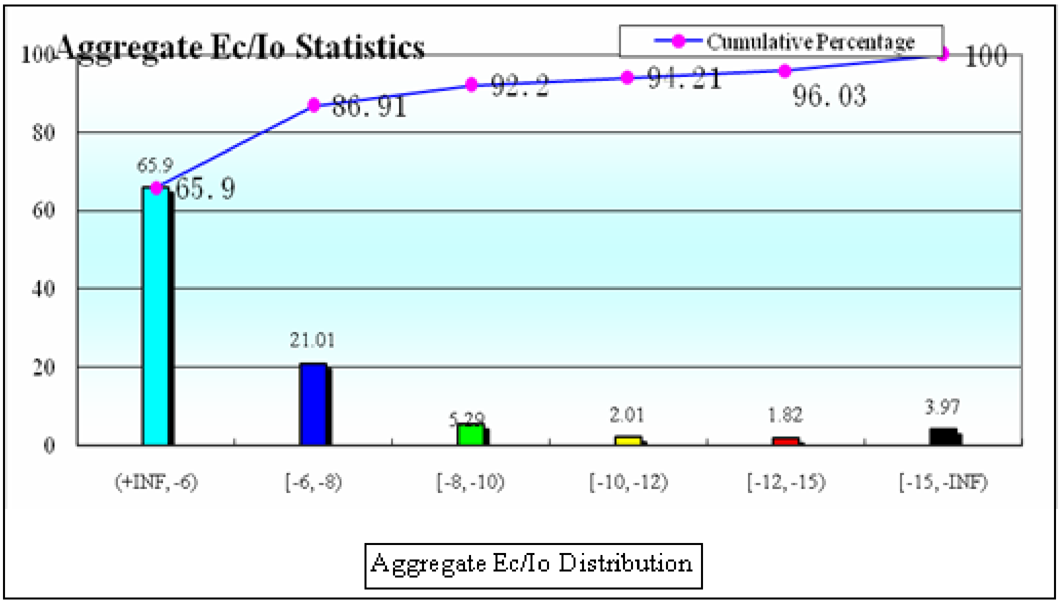


Figure 4.19: Aggregate Ec/Io.

The above Table 4.13 and Figure 4.19 show the statistics, the total Ec/Io greater than -10dB consists over 90% of the drive test area, which is good but there is still 10% need to be optimised for better service.

4.7.3 Reverse Transmit Power

TX reflects the reverse coverage performance.

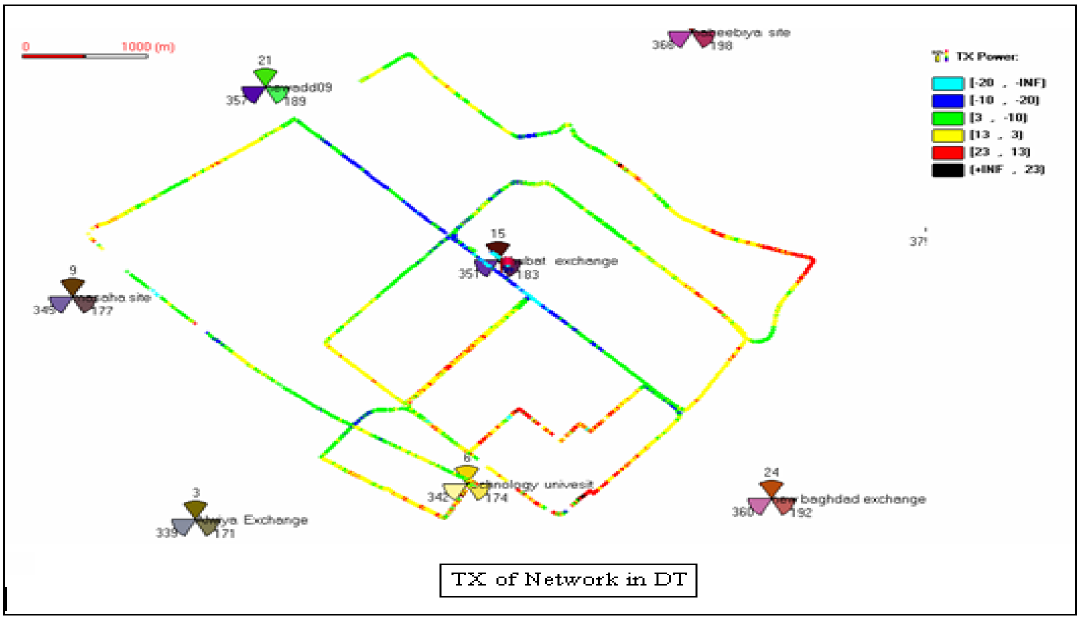


Figure 4.20: Reverse Transmit power measurements route

The above Figure 4.20 show the route taken for measuring the transmit power for BTS site 2 and surrounding area.

Table 4.14: Reverse Transmit Power Distribution

Category	(-INF, -20]	(-20, -10]	(-10, 3]	(3, 13]	(13, 23]	(23, +INF)
Percentage	5.25	6.08	28.12	47.19	12.86	0.5
Count	552	639	2958	4963	1353	53
Cumulative Percentage	5.25	11.33	39.45	86.64	99.5	100
Cumulative Count	552	1191	4149	9112	10465	10518

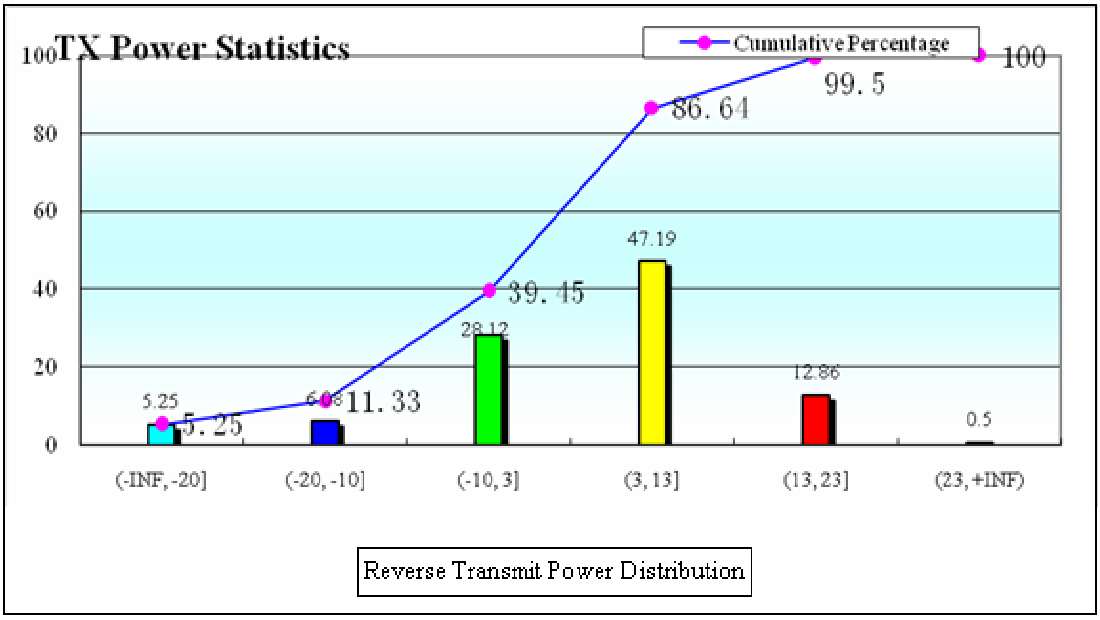


Figure 4.21: TX Power Statistics

The above Table 4.14 and Figure 4.21 clearly show there is an issue with the Reverse Transmitting Power. Only 40% of the measurements are regarded as good for indoor and outdoor service. For 47.19% the indoor service can not be guaranteed and for 12.88% the coverage poor and even the outdoor coverage can not be guaranteed.

Mobile Station received power and strongest pilot Ec/Io is maintained in good state i.e., such as Rx Power>-85dBm, Ec/Io>-12dB; After MS origination, reverse Tx power is increasing continuously, until 23dBm for over almost 60% of the service area, so the above case, MS Rx power and pilot Ec/Io are all good, and this means that the forward link is good. But in the MS origination procedure, MS is increasing transmitting power until maximum, and this means the reverse link is bad.

That results is forward and reverse imbalance. Tx_Adj>0 also means forward is better than reverse, so in the edge of coverage BTS can not receive the signal from MS correctly and BTS call drop mechanism is triggered, and then call drops will happen.

Forward and reverse link imbalance includes two kinds: forward is better than reverse; reverse is better than forward. In our case is the former. The subscriber cannot tolerate call failure and call drops will happen when there is poor signal in Mobile Station, so this case should be taken seriously by the operator.

4.7.4 F-FER (Forward- Frame Error Rate)

The forward FER characterises the quality of basic channels in voice service.

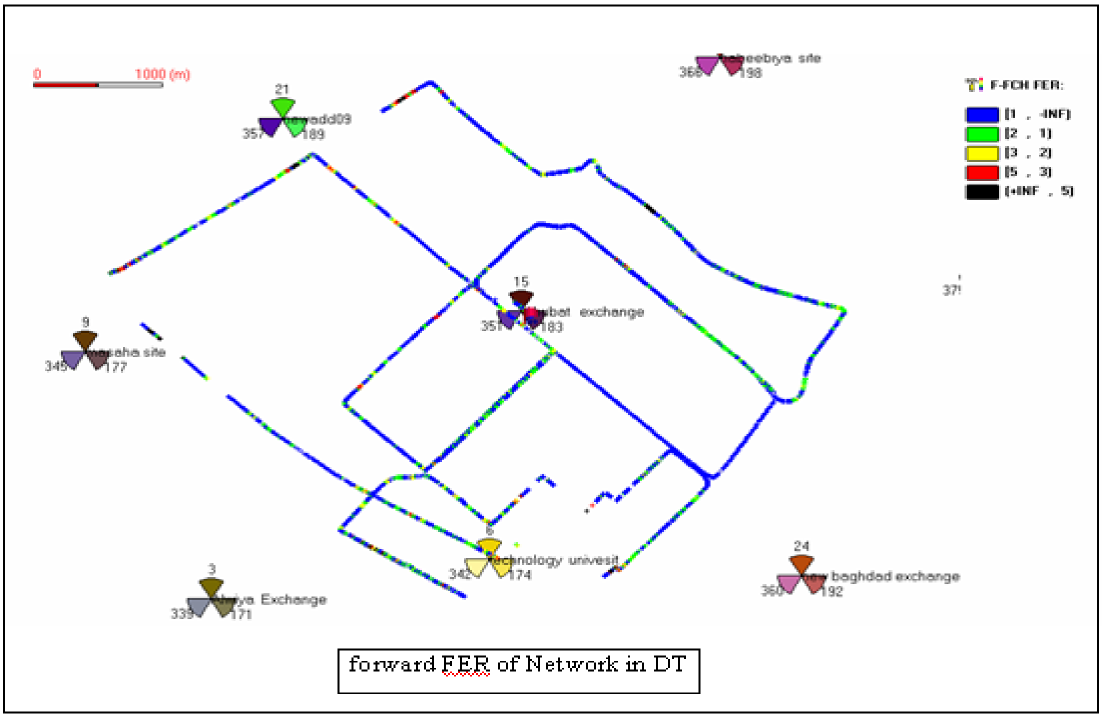


Figure 4.22: Forward FER DT route

The above Figure 4.22 shows the measurement route for the Forward Frame Error rate taken for site 2 in Baghdad.

Table 4.15: Forward FER Distribution

Category	(-INF, 1]	(1, 2]	(2, 3]	(3, 5]	(5, +INF)
Percentage	69.67	20.25	5.07	2.47	2.54
Count	6589	1915	479	234	240
Cumulative Percentage	69.67	89.92	94.99	97.46	100
Cumulative Count	6589	8504	8983	9217	9457

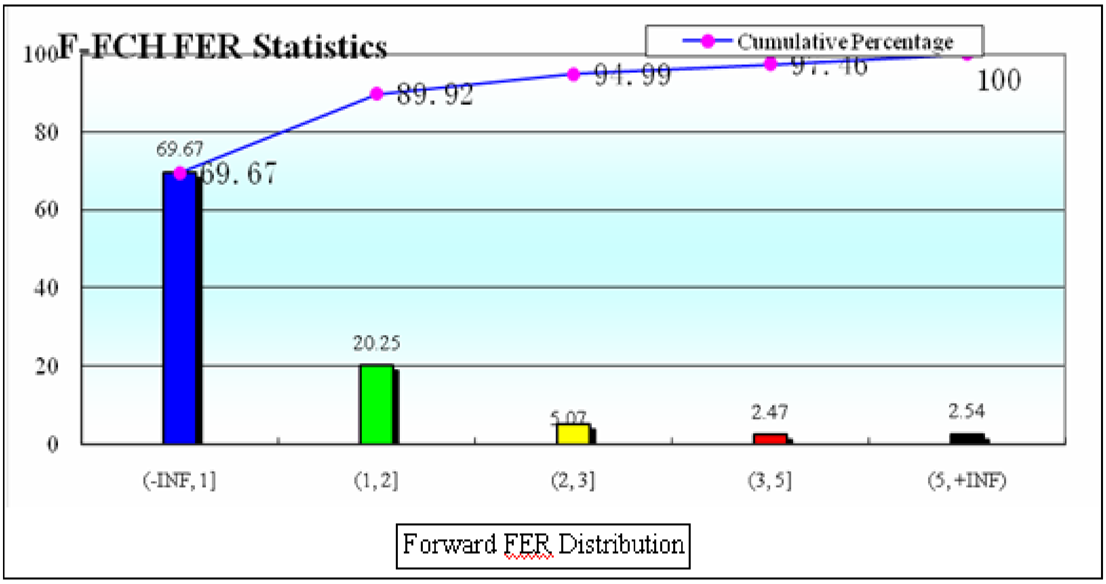


Figure 4.23: Forwards FER distribution

The above Table 4.15 and Figure 4.23 shows above 90% having good voice quality but still about 6% the quality is poor and subscribers can detect this easily.

The value of FER lower than 2% was 91.99% this should be improved after optimisation, and the value should go up came to 96 % or more to have better QoS.

4.7.5 Tx_Adj distribution

Tx_Adj reflects closed-loop power control adjustment. Usually, Tx_Adj range should be 0 <Tx_Adj≤ -10dBm. Too high value or too low Tx_Adj values are an indication of forward and reverse links are not balanceable. Too low value Tx_Adj indicates reverse link is better than forward link, or reverse link initial power is too high; too high Tx_Adj indicates forward link is better than reverse link, or there is reverse interference.

Table 4.16: Tx_Adj distribution

Category	(-INF, -10]	(-10, 0]	(0, 5]	(5, 10]	(10, +INF)
Percentage	0.35	1.59	6.51	18.15	73.4
Count	37	167	685	1909	7720
Cumulative Percentage	0.35	1.94	8.45	26.6	100
Cumulative Count	37	204	889	2798	10518

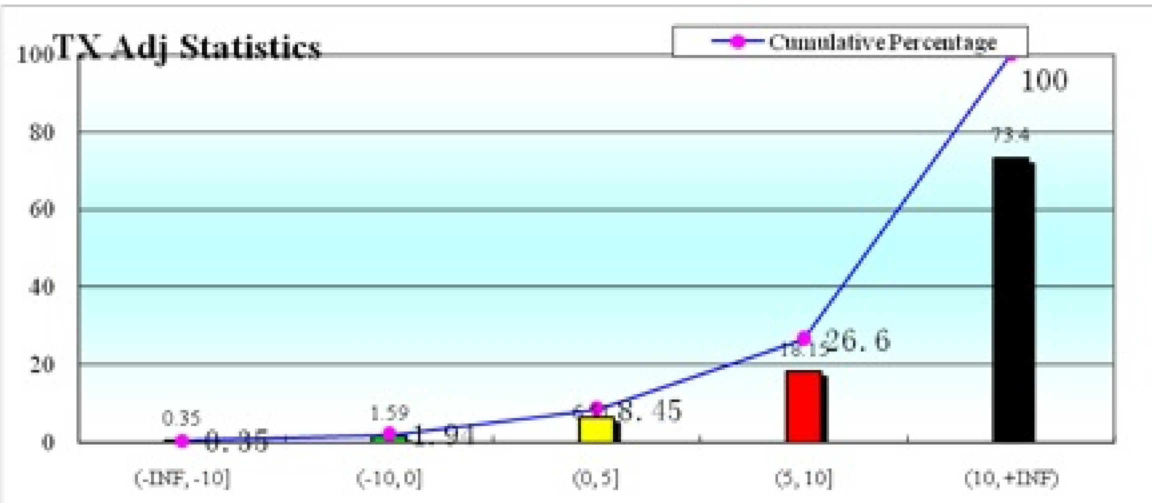


Figure 4.24: Tx_Adj Distribution

The Table above 4.16 and Figure 4.25 indicate clearly there is reverse link that is not balance with over 70% over 10dBm. This problem is normally caused by boomer sites with an elevated antenna radiation centre. The BTS forward link covers distant areas or deep inside buildings where the reverse link of a mobile cannot reach back to the base station. In this case, excessive forward link traffic channel power is always allocated to compensate for the path loss. Link imbalance areas typically can be identified if the forward link coverage is sufficient good pilot Ec/Io See figure 4.20 but call setup failure is high due to exhausted mobile transmit power on the reverse link.

These problems can only be detected by drive tests within the site which have the problems to help the operators to make decisions on where to install new base stations and how to select their configuration, including antenna height and tilt, sector orientations, maximum emission power, pilot signal.

4.8 Summary

This chapter developed detailed measurements analysis of Baghdad CDMA Network and found that there is a lack of efficient planning and optimisation of the ITPC CDMA networks. Planning of network and optimisations are key to guaranteeing superior QoS and user satisfaction.

ITPC as CDMA network operators have various solutions, both short term and long term, to enhance their system capacity. There is a clear issue and problems found during the drive test such as forward and reverse link imbalance for almost all the networks and improper RF parameter settings could lead to under utilisation of system capacity. There are radio parameters that need to be adjusted to enhance the QoS. The threshold values of the parameters must be used as performance indicators to effect radio interface optimisation. Handoff failure is another reason noticed for call drops, when MS moves from one cell to another cell, signal of the current cell will become worse and worse, F-FER and R-FER will be very high, then call drops will happen. This problem can be investigated and corrected with the sectors directions, which will enhance the handoff process and avoid the drop in calls during the movement between the running sites.

Also there is still weak coverage in some parts of the network. The coverage will become good after installing more BTS i.e. Baghdad need more sites to have good coverage so there is a need to restudy RF city plan.
The load on the system increases with time, thus affecting the network performance and QoS, hence the need to periodically monitor the carrier loads, and expand the network if necessary. Frequent drive tests need to optimise the networks especially when new BTS are added to the networks since these will enhance the coverage and overall performance of the network.

Interference affects network capacity and the overall performance and quality of end user experience (call setup, call drop rate, etc) as there is 4 CDMA operators in Baghdad and not enough Guard Band. Also the antenna hardware changes like tilt and azimuth are important issues in the network optimisation which need to be adjusted for best performance.

The Network and optimisation process is a long term process to predict the demand service areas and improve QoS, which requires the study of the network layout and QoS before implementing provision of solutions to weak sites which needed to be sorted out first, for a successful outcome.

Chapter Five

5.0 GSM Performance Measurements and QoS.

5.1 Introduction

The number of GSM subscribers has seen rapid growth in the past decade, so much so that cellular penetration leapt from a 0.3% in 2003 to almost 77% of the population at the end of 2011, still leaving plenty of room for growth in the coming years.

Iraq's GSM market is one of the least developed in the Middle East, with only Palestinian Territory (73%), Syria (60%), Afghanistan (59%) and Yemen (49%) offering a lower level of penetration in December 2011. Subscriber uptake has begun to slow, however, as the market inches closer to saturation; at the end of 2011 Iraq was home to over 24.56 million mobile customers, representing a 7.6% annual increase – compared to 13.8% recorded in 2010 and 39.0% in 2008, and down from the boom rates of 2,360% and 218% experienced in 2004 and 2005 respectively. [Telegeography, June 2012]

Iraq has three mobile Operators namely Zain, AsiaCell and Korek and all suffer from performance and QoS issues and for this reason we have collected data from all the three GSM operators to get accurate measurements on system performance. The accuracy of data statistics is a function of the amount of data on which it is based. To be able to compute KPIs (Key Performance Indicators) with a specified accuracy, so a collection of a data sample of appropriate size from all operators in different locations.

5.2 KPI Data Measurements Size

The larger the measurement sample taken, the more reliable the measurements. Given a desired level of accuracy, the required sample size may be calculated as follows.

If we denote the sample size by *n* and the estimated proportional frequency (i.e. the measured KPI) by *f*, then, using the Gaussian approximation of the binomial distribution, we obtain the 95% confidence interval (CI) for the true proportional frequency *p* as

$$p = f \pm 1.96.\sqrt{\frac{f(1-f)}{n}}$$

This means that the true proportional frequency p falls within the confidence interval

$$f - 1.96.\sqrt{\frac{f(1-f)}{n}}, \qquad f + 1.96.\sqrt{\frac{f(1-f)}{n}}$$

with 95% probability. [Ericsson, 2006].

In other words, if we want a confidence interval [$f - e$, $f + e$] for p, the required sample size is approximately

$$n = \frac{1.96^2}{e^2}.f.(1-f)$$

The Attach Failure Ratio for packet-switched is estimated at f = 10% with a sample size of n_1 = 200 measurements. By the formula for p, the uncertainty of the measurement at the 95% confidence level is e1 = 4.16%. Thus, with 95% probability, the true proportional frequency p falls within the interval [5.84%, 14.16%].

To reduce the uncertainty to ±3% at the same confidence level, a sample size of $n2=(1.96^2/0.03^2)*0.1*0.9=384$ would be needed. [Ericsson, 2006]

In practice, at least 200 measurements should be performed for all KPIs defining success or failure ratios, and preferably 500 if at all practicable.

5.3 Measurements of Speech Quality

TEMS (Test Mobile System) measures SQI (Speech Quality Index) for estimating the downlink speech quality in a GSM cellular network as perceived by a listener. So we measure the quality by collecting the required data collected with Sony Ericsson phones.

SQI is a feature of TEMS. It takes the following parameters as input:

Frame Error Rate (FER), i.e. the percentage of frames that are lost on their way to the receiving party, usually because of bad radio conditions.
Frame errors also occur in connection with handover, and these are treated like any other

frame errors by the SQI algorithm. In GSM, on the other hand, every handover causes a number of frames to be lost.

Bit Error Rate (BER). This is end-to-end measurements performance. The bit-error rate (BER), which quantifies the reliability of the entire radio system from “bits in” to “bits out,” including the electronics, antennas and signal path in between.

The speech codec used. The general speech quality level and the highest attainable quality vary widely between codecs. Moreover, each speech codec has its own strengths and weaknesses with regard to input properties and channel conditions. The same basic SQI-MOS (Speech quality index - Mean Opinion Score) model is used for all supported speech codecs, but the model is tuned separately for each codec to capture its unique characteristics. [Ericsson, 2008]

The SQI algorithm produces a new quality estimate at intervals of approximately 0.5s. Such a high update rate is possible due to low computational complexity of the algorithm.
The output from the calculation is a score on the ACR (Absolute Category Rating) scale widely used in listening and familiar to cellular operators. The score is thus a value ranging from 1 to 5.

The SQI-MOS algorithm has been designed to correlate its output as closely as possible with the PESQ measure (Perceptual Evaluation of Speech Quality). In fact, the SQI-MOS models have mostly been calibrated using PESQ scores, rather than actual listening tests, as benchmarks. The exception is the wideband modes, where adjustments to the models have been made using the results of external listening tests.

PESQ measures the quality end-to-end, that is, also taking the fixed side into account, whereas SQI reflects the radio link quality only. This means that PESQ and SQI values may differ while both being accurate in their respective domains.

Also bear in mind that PESQ and SQI-MOS use fundamentally different approaches to quality measurement:

· PESQ is a reference-based method which compares the received degraded speech signal with the same signal in original and undistorted form.

· SQI-MOS, on the other hand, is a no-reference method that works with the received signal alone and extracts radio parameters from it.

Both methods try to assess to what degree the distortions in the received signal will be audible to the human ear; but they do it in completely different ways.
PESQ scores need to be averaged over a range of speakers in order to eliminate speaker bias. Such averaging is not required in the case of SQI-MOS, since the speaker-contingent variation is already built into the model (it has been trained with a large number of speakers). [Ascom, 2009]

The speech quality in GSM networks was often measured by means of the RxQual parameter (which is also available in TEMS) but since RxQual is merely a mapping of time-averaged bit error rates into a scale from 0 to 7, it will only provide a rough indication of speech quality.

5.4 Zain Measurements

Data was collected for the three GSM Operators using TEMS and will be analysis starting with the Zain Iraq as the largest of the GSM operators in Iraq then AsiaCell and Korek.

GSM Measurement Charts – These charts provides a time- series view of RxLevSub and RxQualSub. The vertical black bar denotes the currently selected message. RXLEvel is the Level of Received signal strength. RxLevel is received power level at MS (maximum RxLevel measured by MS is – 40 dBm.

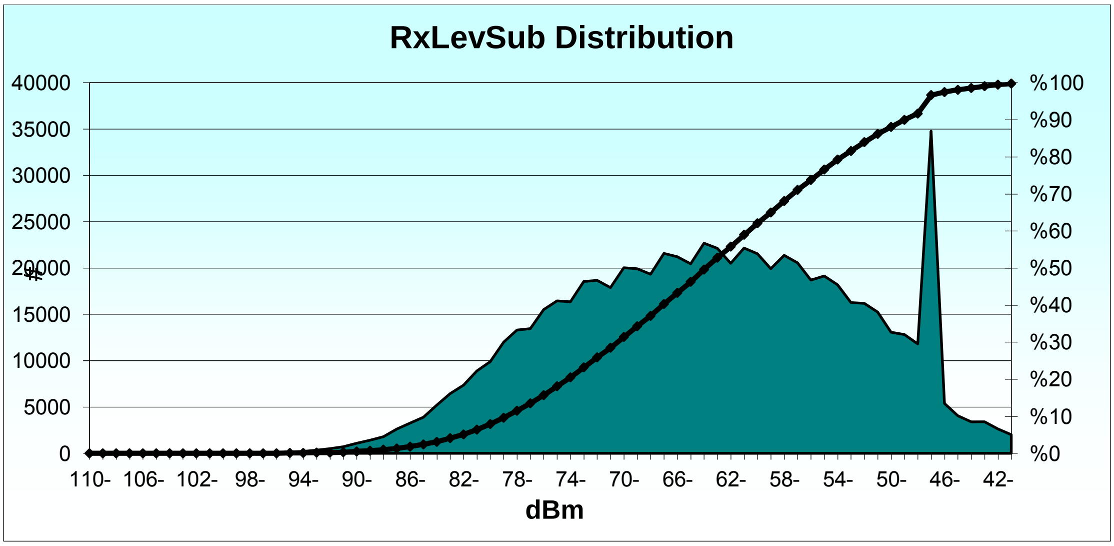


Figure 5.1:Zain RxLevel Measurements

In GSM, there are two types of values presented for RxQual, namely RxQual Full and RxQual Sub. RxLev, is the parameter representing the signal strength, which also has similar Full and Sub values. See Figure 5.1 and Figure 5.2.

RX Lev Sub: When the mobile is used in conversation, 40% of the time either Transmitter or Receiver is idle. When DTX (Discontinuous Transmission) is ON, DTX will switch off the Transmitter or Receiver when there are no speech pulses. Only few TDMA frames will transmit, and the average of these TDMA frames is called RX Lev Sub. These provide the proper measurements of RX level.

Rx level 0 to 63 is GSM unit. While -110 to -42 is dbm. When we will add 110 to Rxlevel [dbm],it will get convert into GSM unit 0 to 63. See Figure 158.
For coverage point of view we use RX Level Full values. Operators regarded measurements as follows: 0 to -75 is Good, -75 to -85 is acceptable and -85 to -110 is Poor.

Rx Qual is a value between 0 and 7, where each value corresponds to an estimated number of bit errors in a number of bursts. See table 5.1.

Each RxQual value corresponds to the estimated bit- error rate according to the following table.

Table 5.1: BER to RxQual conversion

RxQual	Bit Error Rate (BER)
0	BER < 0.2%
1	0.2% < BER < 0.4%
2	0.4% < BER < 0.8%
3	0.8% < BER < 1.6%
4	1.6% < BER < 3.2%
5	3.2% < BER < 6.4%
6	6.4% < BER < 12.8%
7	12.8% < BER

The RX Quality is a parameter, which represents the estimated quality in terms of BIT ERROR RATE (BER). For RX Quality plots we use RX Quality sub values as measurements or indicators for QoS. Operators regarded the values of 0 to 3 is Good, 3 to 5 is acceptable and 5 to 7 is Poor. (Table 5.1)

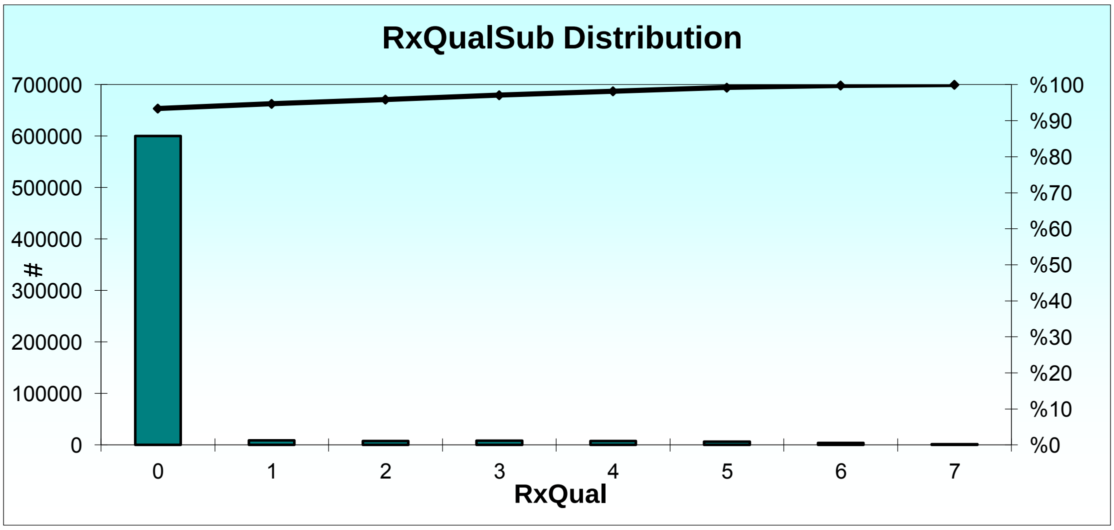


Figure 5.2: RXQual measurements

Timing Advance (TA) value corresponds to the length of time a signal takes to reach the base station from a mobile phone.

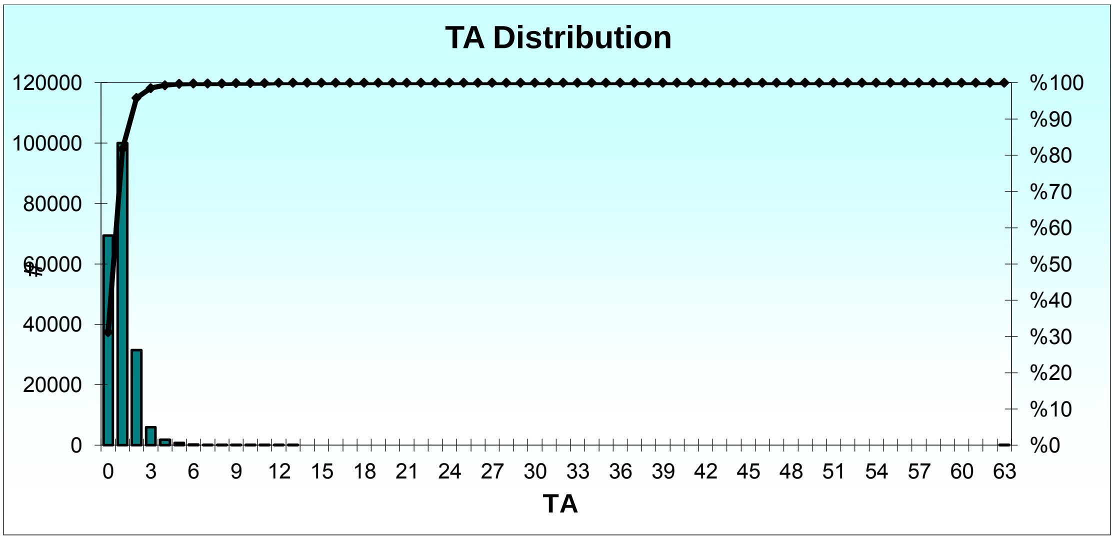


Figure 5.3:Time Advance measurements

The TA signal is transmitted in the SACCH (Slow Associated Control Channel) as a number between 0 and 63, in units of bit periods (3.69 microseconds). If the signal travels at 300 meters per microsecond, each TA travels a distance of approximately 1100 meters. Since this is the round trip distance, each increase in the value of TA corresponds to a distance of 550 meters between the mobile and BTS.

For example, TA = 0 means that the mobile is up to 550 meters from the station, TA = 1 means it is between 550 and 1100 meters, TA = 2, from 1100 to 1650 meters and so on.
The maximum distance allowed by the TA between the MS and BTS is 35 km (GSM 850 / 900) * 63 or 550 meters.

So, for example during a test drive, we can measure how far we are from the BTS through the value of TA (Timing Advance). So, it can be said that knowing the TA, may predict that user distance from the BTS.

If the mobile station moves away from the base station during a call, the further distance the more delay. If the delay is too high, the timeslots of the signal from a certain mobile station and that of the next signal from another mobile station received by the base station will overlap each other, thus causing interference.
So operators need to control interference by continually adjusting the TA, so we have less data loss, and can improve the quality of our signal.

5.4.1 Design Validation

Design Quality

Table 5.2: Design Quality

Good design	90.79%
Bad Design	9.21%

Poor Design by Class

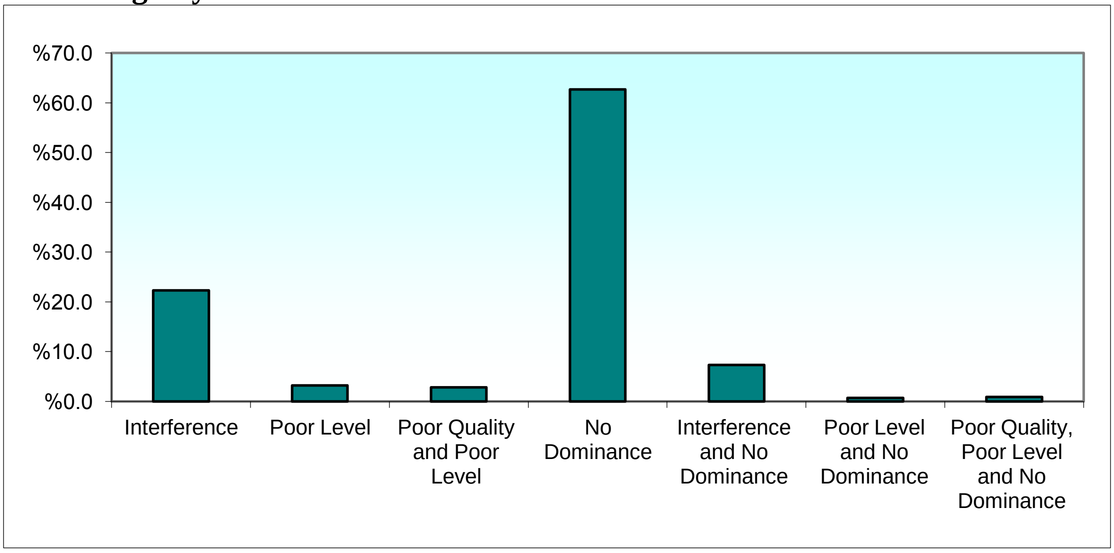


Figure 5.4: Poor Design by classification

The figure 5.4 shows 56% of the poor design with no Dominance i.e. Signals of more than one cell can be reaching a spot with low level causing ping pong handovers. This might happen because the MS is located on the cell borders and there is no any best server to keep the call.

Breakdown of Poor Design
Table 5.3: Poor Design Breakdown Percentage

Cause	Percent
Interference	19.0%
Poor Level	9.6%
Poor Quality and Poor Level	5.0%
No Dominance	56.0%
Interference and No Dominance	5.6%
Poor Level and No Dominance	3.1%
Poor Quality, Poor Level and No Dominance	1.8%

Lack of Dominant Server Causes too many Handovers between the same Cells. (table 5.3)

Table 5.4: Causes of Poor Design

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

No Dominance occurs when there are more than 2 neighbours within 5dB of the server (table 5.4).

The interference that is caused by frequency reuse is called internal network interference or internal system interference. This interference will cause conversion quality reduction, call drop, handover and congestion, and this kind of interference is one of the most important factors that affect the network Quality of Service (QoS) (table 5.4). Thus reducing or eliminating interference is the principal task of Zain Iraq Network planning and optimisation teams.

The design is one of the very important factor in the QoS e.g. if cell sites are designed poorly there might be areas where neighbours being received at the same level and some other neighbour randomly looks good for hand off for a certain amount of time. Such a situation is disastrous because handoff decision will be hard and mostly it will end up unsuccessful handovers.

The solutions for this kind of problems include the antenna tilting to provide the good way to reduce the footprint of the sites. Efforts should be made to ensure that a single dominant server should serve a specific area. Timing advance limitation is applied to cell areas where there are multiple servers.

5.4.2 Neighbour Level (Single Band)

Handover Area (not valid for dual band networks)

For sudden increase and decrease in Neighbour's Level or too frequent handovers will cause Sudden Appearance of Neighbours and this Due to terrain or obstacles, neighbours may pop up with high levels causing the BSC to give wrong handover decisions. In this case, there won't be a stable server, but the call will be handed to the neighbours for very short period.

Table 5.5: Neighbours measurements

Number of Neighbours	PDF	CDF
0	14.06%	14.06%
1	36.32%	50.38%
2	21.05%	71.43%
3	10.72%	82.15%
4	6.01%	88.15%
5	3.92%	92.07%
6	7.93%	100.00%

In the above Zain Measurements provided by mobile terminals, where the measured Rx_Lev from the serving cell as well as up to 6 neighbouring cells is reported, are collected. See above Table 5.5 and Figure 5.5.

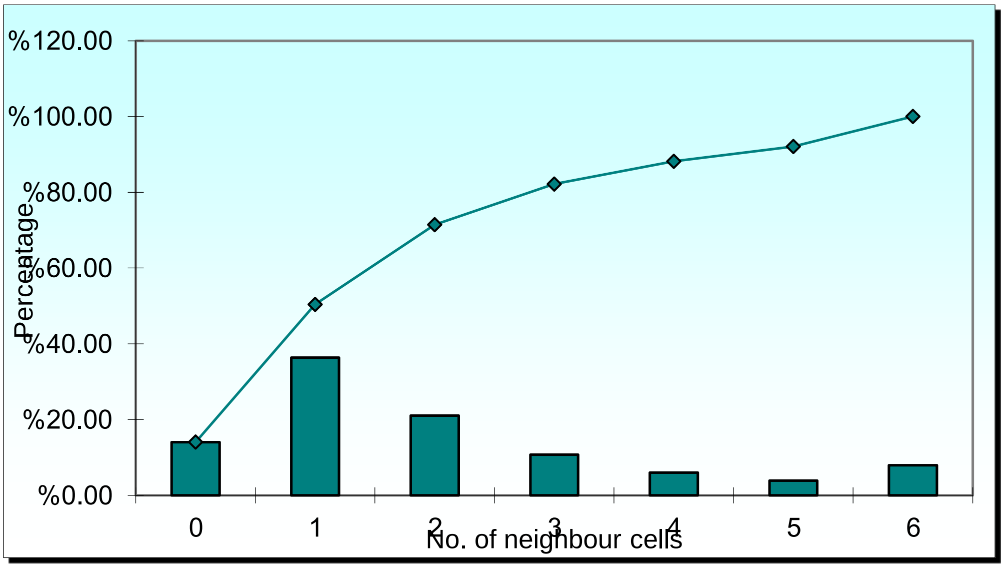


Figure 5.5: Call Details

In order to measure the network performance a daily congestion situations should also be analysed. Following KPIs are more important for GSM radio network optimisation & benchmarking to achieve acceptable QoS i.e. CSSR (Call Set up Success Rate),

CDR (Call Drop Rate), Handover Success Rate, TCH (Traffic Channel) Congestion Rate. RX

Level and RX Quality.

Table 5.6: Call Control Messages

CC Messages	Count
CC Setup	91
CC Call Confirmed	18
CC Connect	67
CC Alerting	90

Table 5.7: Radio Resource Messages

RR Messages	Count
RR Handover Command	4049
RR Handover Complete	3986
RR Handover Failure	83

Table 5.8: Multi Media messages

MM Messages	Count
MM Location Updating Request	266
MM Location Updating Accept	261
MM Location Updating Reject	0

Table 5.9: Event measurements

The Events	Count
Outgoing Call Starts	69
Outgoing Call Setup OK	60
Outgoing Call Setup Failure	**11**
Incoming Call Starts	5
Incoming Call Setup OK	17
Incoming Call Setup Failure	**1**
Call Completed	46
Call Dropped	**16**
Handover OK	3965
Handover Failure	**83**
Location Update OK	261
Location Update Failure	**4**

The above table 5.6, 5.7, 5.8, 5.9 mentioned KPIs are frequently used in performance judgment and QoS estimation of the network.

The CSSR (CALL SET-UP SUCCESS RATE) Rate of calls attempts until TCH successful assigned. CSSR might be affected and degraded due to different issues i.e. Due to radio interface congestion, lack of radio resources allocation, Increase in radio traffic in inbound network, Faulty of BSS Hardware and Access network transmission limitation.

CSSR 1:	(Calls Completed + Calls Dropped) / Call Attempts
CSSR 2:	Outgoing and Incoming Call Setup / Call Attempts
CCR 1:	Calls Completed / Call Attempts
CCR 2:	Calls Completed / Calls Setup OK
HSR:	Handovers Successful / Handover Attempts
LUSR:	Location Update Successful /Location Update Attempts

Call Setup Success Rate (CSSR)	83.78%	104.05%
Call Completion Rate (CCR)	62.16%	59.74%
Handover Success Rate (HSR)	97.93%	
Location Update Success Rate (LUSR)	98.12%	

Table 5.10: Calls measurements

CDR (CALL DROP RATE) Rate of calls not completed successfully.

CDR might be affected due to different reasons i.e. Interference being observed over air interface. Internal interference corresponds to one of the in-band (900/1800 MHz) while external Interference corresponds to other wireless usually military networks which Iraq suffered a lot of this during the Multi National forces and still due to bad spectrum management regulations, Coverage limitation another factors which increase CDR values., Hardware faults such as BTS transceiver can also be incorporated in an increasing CDR, Missing adjacencies is also another important factor in CDRvalues increment (table 5.10).

Iraqi operators has many investigations to improve the performance and has clearly shown that a lot of external interference exists on the current GSM band and it is affecting many cells. They had workaround of moving TSs to the less interfered band on some cells improved the performance although degraded the voice performance on those cells. However, all the measurements taken on the 900 band are focused on improving the performance on certain cells.

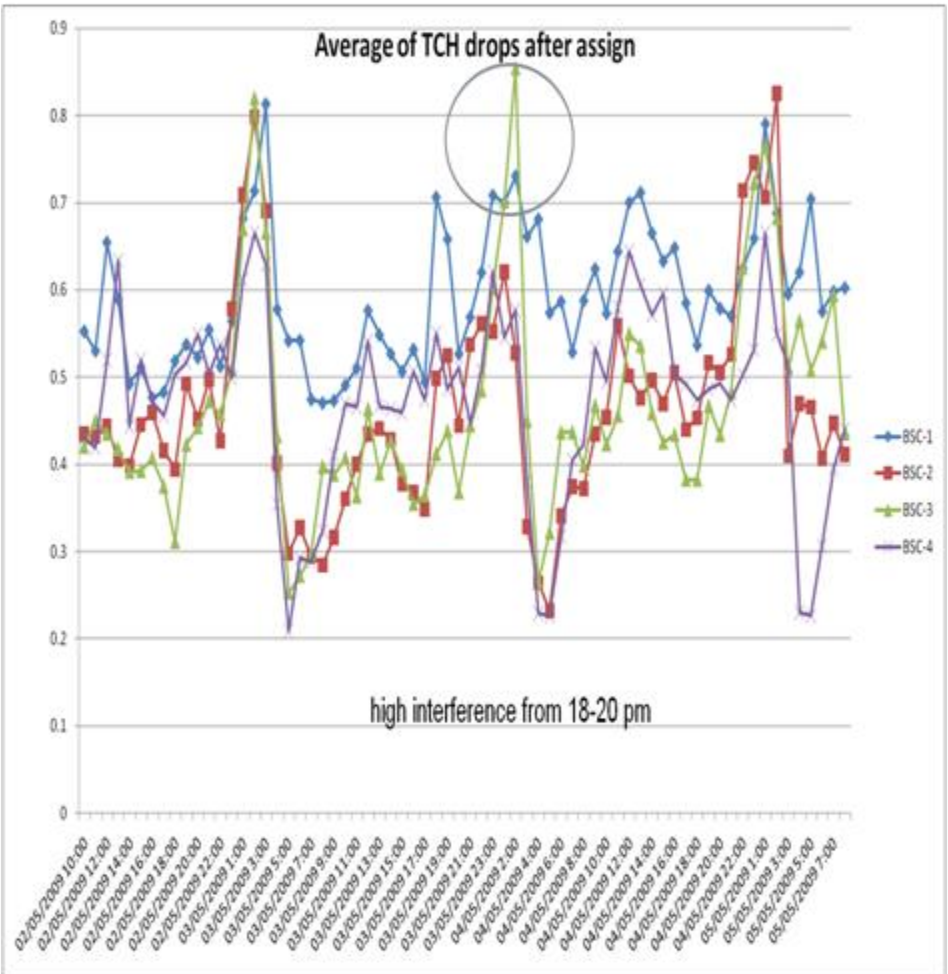


Figure 5.5a: High Interference measurement

The external source of interference evidence shown above show hourly stats TCH drop for all BSC for three days. From the graph the peak TCH drop is happing from 18 to 20 pm on 3May. This is the same when high UL interference occurs. This is strong evidence for the latest high drop call due to external source.

HANDOVER SUCCESS RATE (HSR) Rate of successful handovers (intra cell +intra cell). HSR effected and degraded due to many reasons:

Interference being observed over air interface, which affect on going call switching in case of Handover, Missing adjacencies can also result in degradation, Hardware faults, Location area boundaries wrongly planned and/or defined and Coverage limitation is also one of the factors.

5.4.3 Neighbour Level (Dual Band)

900	29.43%
1800	70.57%

Table 5.11: Frequency Bad usage

Dual band topology in GSM networks is very common in the Mobile markets. The primary reason for this is the lack of frequency spectrum available. Therefore, network operators are utilising both Bands i.e. 900Mhz and 1800MHz. See table 5.11 and figure 5.6. However, operating a dual band GSM network requires end to end optimisation.

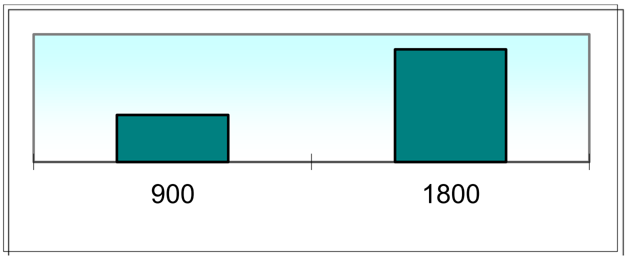


Figure 5.6: Frequency Bad Usage

Intracell handover is also possible between different GSM bands (Dual Bands). Thus, a GSM cell in the 900 MHz band is quite able to use voice channels in the 1800 MHz band, which bring enormous stress factor on the mobile phone since it is constantly required to switch the frequency bands, In addition to the voice connection in the 1800 MHz band, it must also cyclically analyse the BCCH information in the 900 MHz band. This ”stress” on the mobile phone and the high performance speed make this handover favoured test and measurements method in production which we have carried out.

Table 5.12: Intra and Inter Bands

Intra Band	0.00%
Inter Band	100.00%

Neighbours within 5 dB from server

Table 5.13: Neighbours sites

	Intra Band		Inter Band	
Number of Neighbours	PDF	CDF	PDF	CDF
0	17.67%	17.67%	57.54%	57.54%
1	41.02%	58.69%	23.59%	81.13%
2	20.41%	79.10%	10.76%	91.89%
3	9.56%	88.66%	4.70%	96.59%
4	5.68%	94.34%	2.20%	98.79%
5	2.87%	97.21%	0.83%	99.62%
6	2.79%	100.00%	0.38%	100.00%

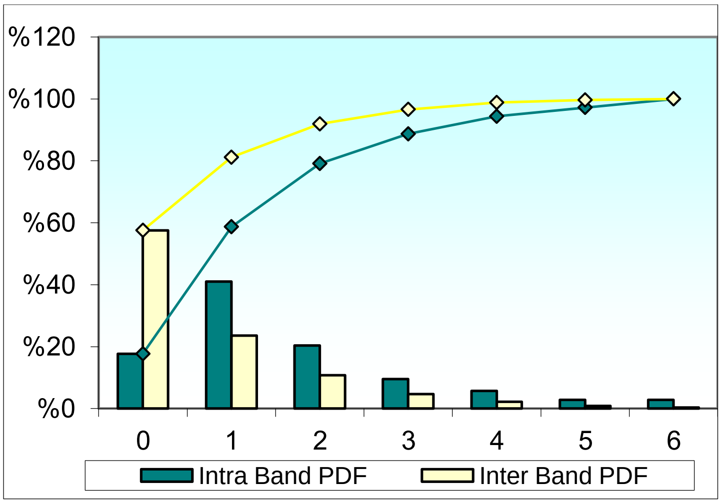


Figure 5.7:Neighbours Sites

If a dual-band GSM mobile phone user starts conversation in an area covered by operators using GSM 1800MHz, after leaving this coverage area, it hands over to the GSM 900MHz cell where it originally was. And the handover of this type is called the inter-band handover caused by coverage. See Table 5.13 and figure 5.7.

If a dual-band GSM mobile phone users starts the conversation in an area covered by GSM 900MHz, but because the traffic in this area is great, the mobile phone will hand over to an area covered by GSM 1800MHz. The handover of this type is called the inter-band handover caused by capacity. See Table 5.13 and Figure 5.7.
Frequent inter-band frequency handover increase the signalling load, which results in the loss of system capacity.

5.5 Asiacell Measurements

AsiaCell is the second GMS operator in the Iraqi Market With time, both operators Zain and AsiaCell experienced an unprecedented growth in customer base with over 20 Millions users Although, this explosive growth has brought huge revenue to both the operators and government through tax and license fee. Many problems occurred like: Instability in power supply, Security of infrastructure, Inter-Network connectivity, Network congestion, Call setup failure and Call retention / call drop.

All these factors contribute in one way or the other to the poor quality of services and bad performance rendered by main GSM operators in Iraq.

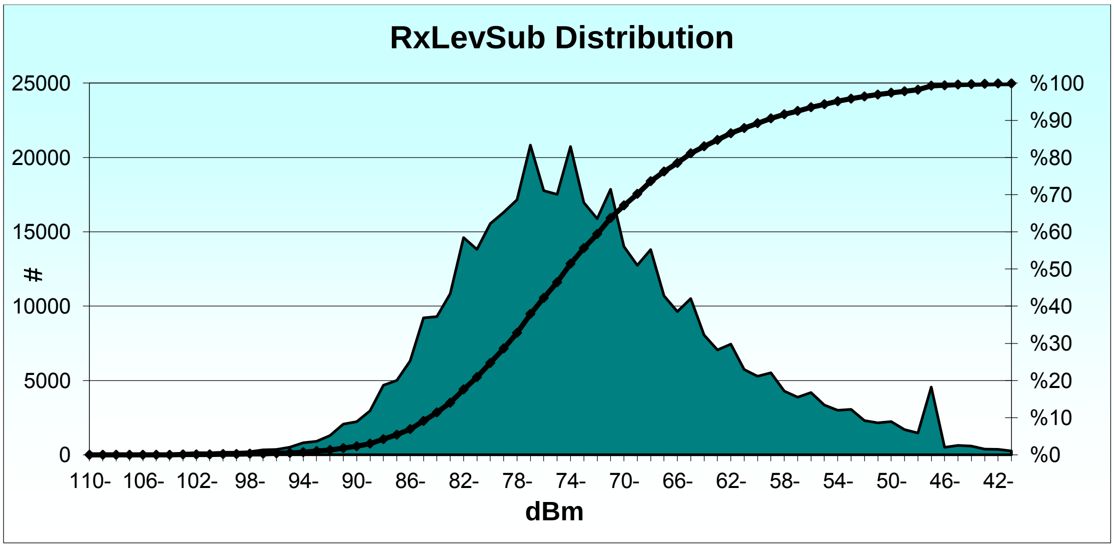


Figure 5.8: AsiaCell RxLevSub Measurements

The QoS and Performance measurements for the Voice quality represented by two main parameters RXLEV and RXQUAL parameters. RXLEV is the absolute field strength received by the mobile phone, while RXQUAL represents the technical quality of the radio link.

The main factors affecting these parameters are the transmission power from the base transceiver station (BTS) and the mobile station (MS) and the current BTS load.

The two diagrams figures 5.8 and 5.9 show the distribution of receive levels (the X axis indicates the RX level normalised to ±110 dBm) and the quality values or bit error rates. The Y axis in both diagrams indicates the number of Measurement Result messages.

The distribution maximum should be around -85 dBm, according to experience (the value 0 in the diagram corresponds to ±110 dBm, ±85 dBm is thus the value 25).

From the above chart, the outdoor level is almost in the range of -80 dBm which needs to be improved and biased more towards an average of (-70 to -75 dBm) in order to guarantee good indoor penetration as building loss is to be added. Pointing out poor coverage holes and installing new sites can achieve this.

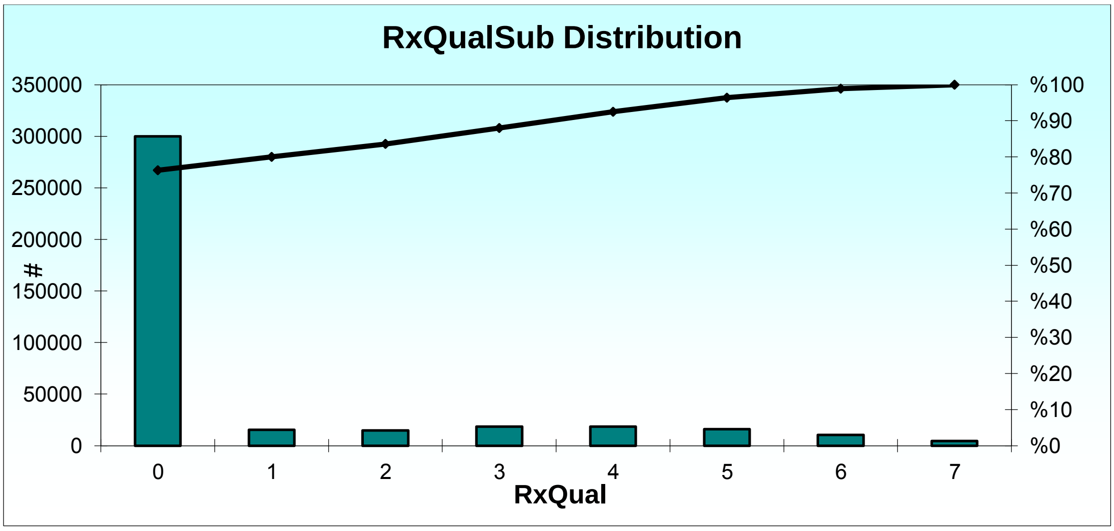


Figure 5.9: AsiaCell RxQual Measurements

The above Figure 5.9 reported value is the average of the BER received over all the frames and rated in one of the eight RXQUAL bands (0 through 7); 0 is the lowest BER i.e. best performance and 7 is the worst case.

RXQual is still giving part of samples in 6 and 7 bands that pointed directly to interference even if Frequency Hopping is activated in the network.

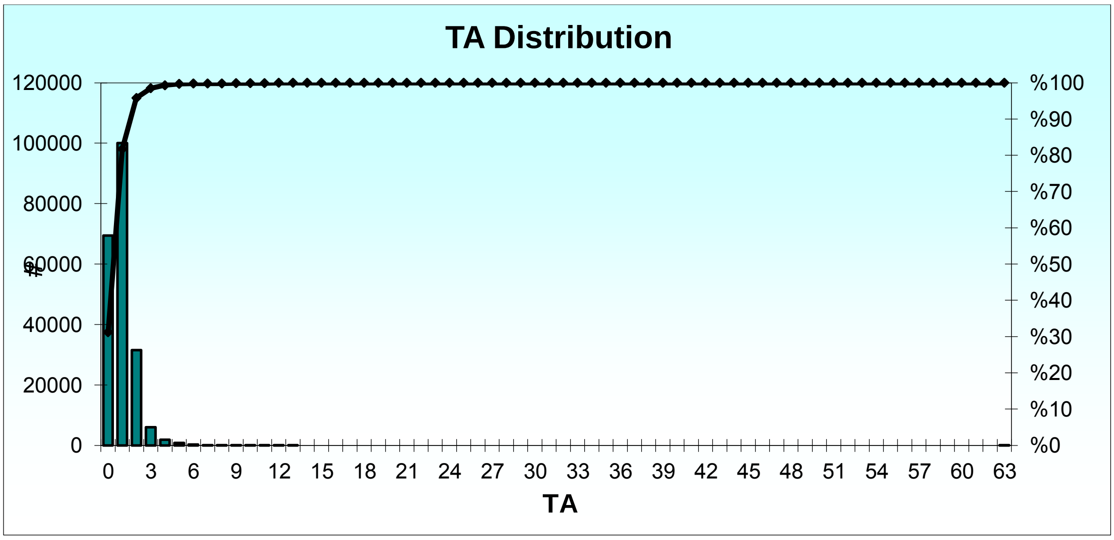


Figure 5.10: Timing Advance

During the DT (drive test) MS caught some calls from far cells that impacted RXLevel and RxQual. Down tilt overshooting cells need to be carried out as well as reducing antenna height for old established sites, which were previously designed to serve large areas due to less number of sites.

5.5.1 Design Validation

Various readings have been taken to validate the design and in different locations the result show more or less similar results.

Design Quality

Table 5.14: design quality

Good design	78.50%
Bad Design	21.50%

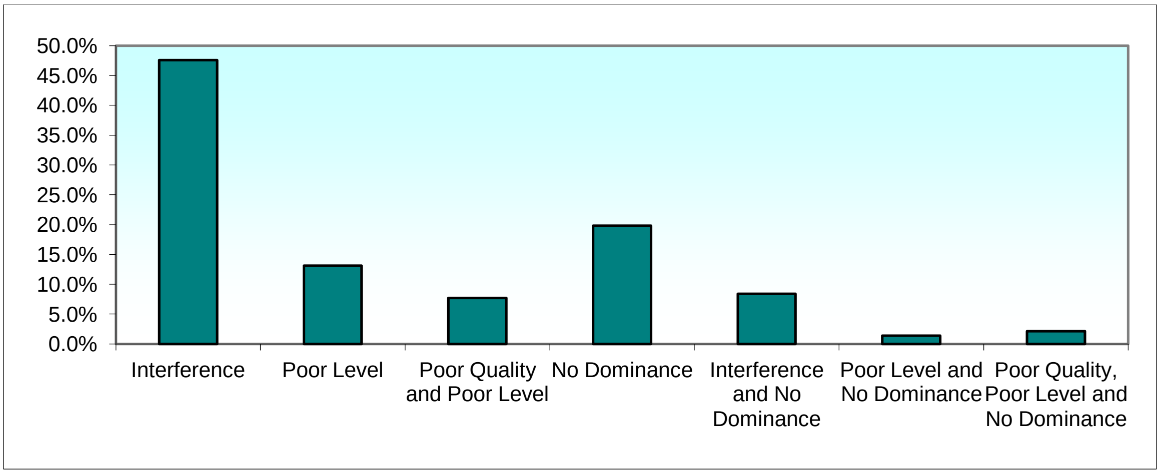


Figure 5.11: Poor Design by Classifications

Table 5.15: Breakdown of Poor Design percentage

Cause	Percent
Interference	47.6%
Poor Level	13.1%
Poor Quality and Poor Level	7.7%
No Dominance	19.8%
Interference and No Dominance	8.4%
Poor Level and No Dominance	1.4%
Poor Quality, Poor Level and No Dominance	2.1%

Table 5.16: Poor Design causes

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

The chart above table 5.15 and 5.16 shows that the number of interference samples is very high and that will impact SQI (speech quality indicator) and handover behaviour (success rate). Furthermore, a considerable amount of no dominancy areas occur that needs to be revised in terms of adding new sites and dominant servers.

5.5.2 Neighbour Level (Single Band)

Handover Area (not valid for dual band networks)

Percentage of samples where at least one neighbours is stronger than the serving cell: 9.37%

Table 5.17:Neighbours Measurements

Number of Neighbours	PDF	CDF
0	17.10%	17.10%
1	15.79%	32.89%
2	12.80%	45.69%
3	10.17%	55.86%
4	8.31%	64.18%
5	6.48%	70.66%
6	29.34%	100.00%

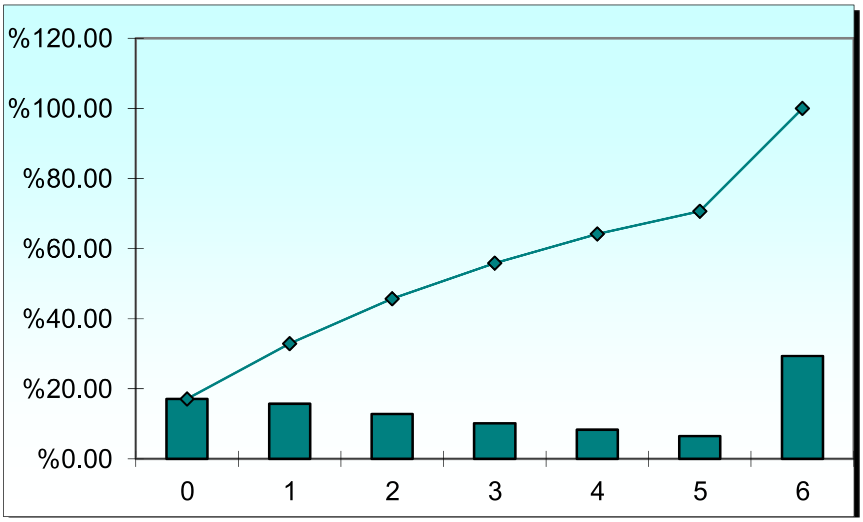


Figure 5.12: Neighbours Chart

The handover measurement data reflects the mobility of the subscribers within the cell under measurement. The Mobiles network will continuously perform measurements on serving neighbouring cells. The measurement results are sent to the BSC and used in the locating procedure to make decisions about handover.

The Measurements contains RXLEV and RXQUAL information of the serving carrier and list of best neighbours sorted by best RXLEV value.

5.6 Korek Measurement

Korek is the Third GSM operator in Iraq and still have limited coverage even they have National License. The company mainly working in Kurdistan and deployed their services in Baghdad and Basra in Q3 2012 after partnership and sold 45% to Orange [France Telecom].

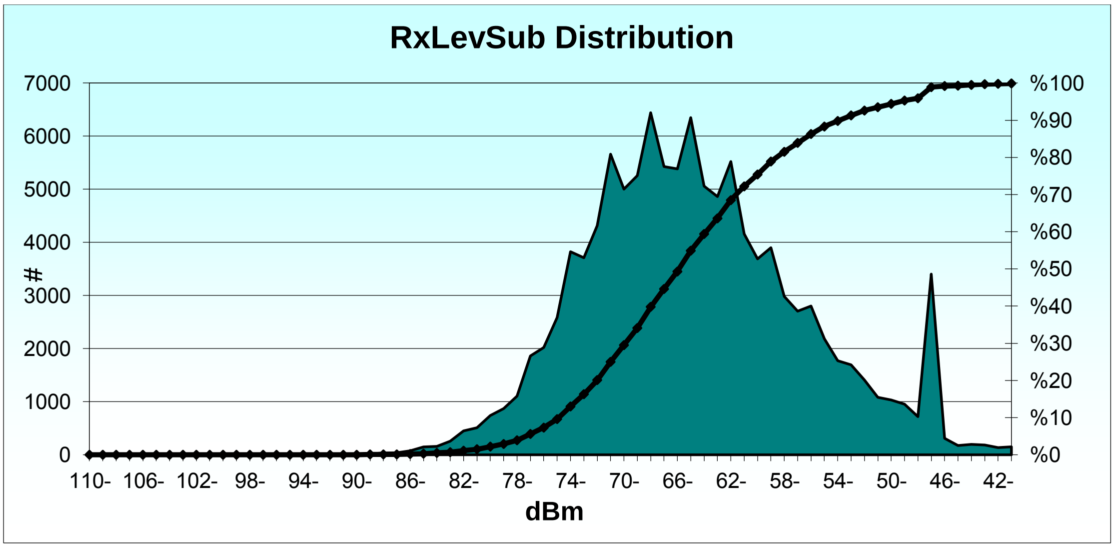


Figure 5.13: Korek RxLevSub measurements

RxLev (Receiving Signal Level) is most important parameters to measure the strength of serving cell and RXQual (Received Signal Quality) based on BER (Bit Error Rate) rating from 0 excellent to 7 bad. (figure 5.14)

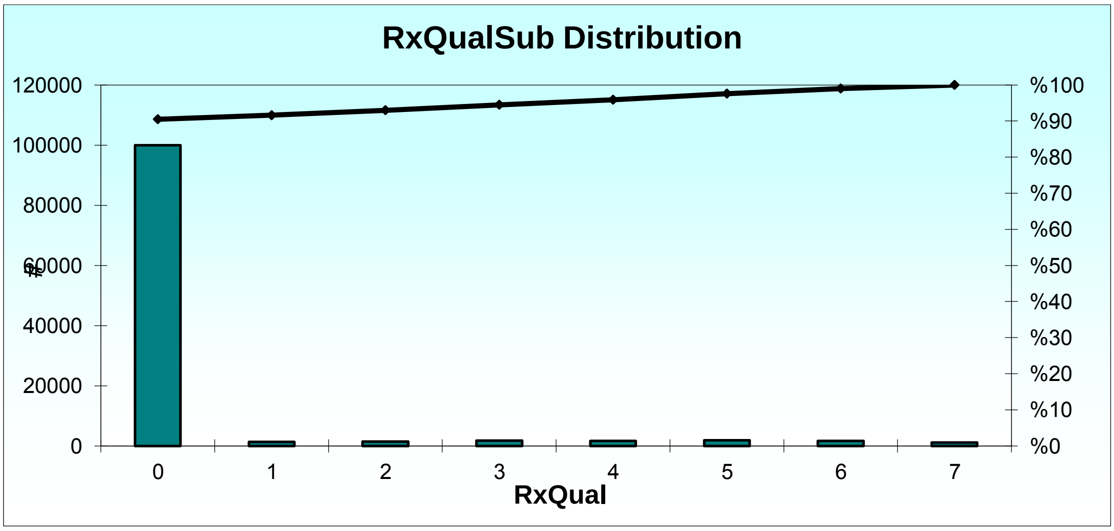


Figure 5.14: Korek RxQual Measurements

The distance calculated from the TA can be used with the distance calculated from the received radio strength from the serving BTS. The result from these two parameters will be the error in the received radio strength. If the difference between the TA and radio results is considerable, the difference can be used to correct the distance results from the other BTSs. (figure 5.15)

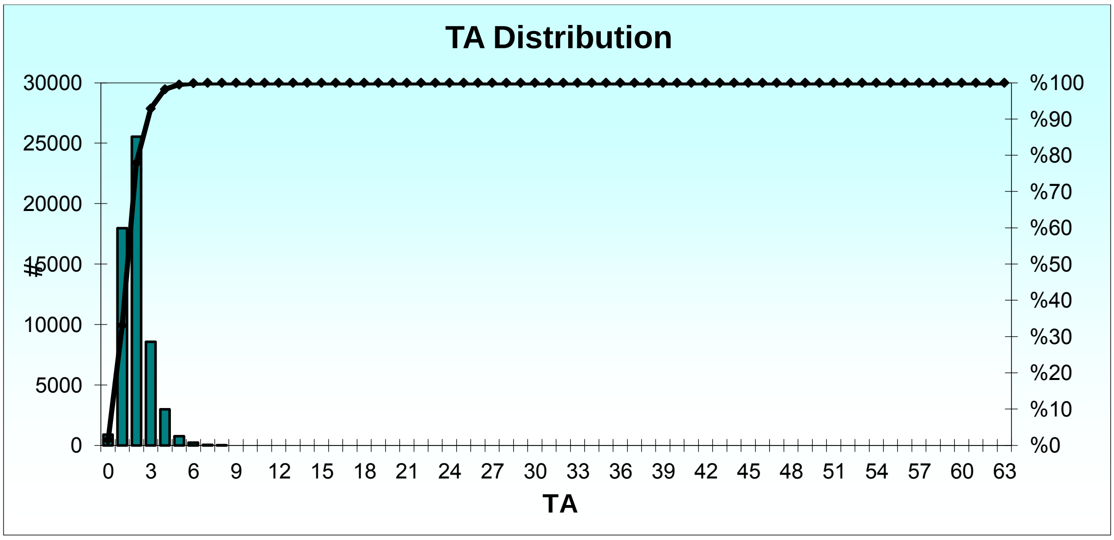


Figure 5.15: Timing Advance

By obtaining Timing Advance (TA) values for different base stations would result in a more accurate location. If a handover occurred during the call, it would be possible to calculate the distance from each of the base stations using the TA values for the stations before and after the handover. This will synchronize the mobile phone to the BTS (Base Station).

5.6.1 Design Validation

Design Quality
Table 5.18: Design Quality

Good design	77.67%
Bad Design	22.33%

Korek bad design is the highest among the three operators followed by Asiacell and the highest in the No Dominance which almost 63%. See table 5.19.

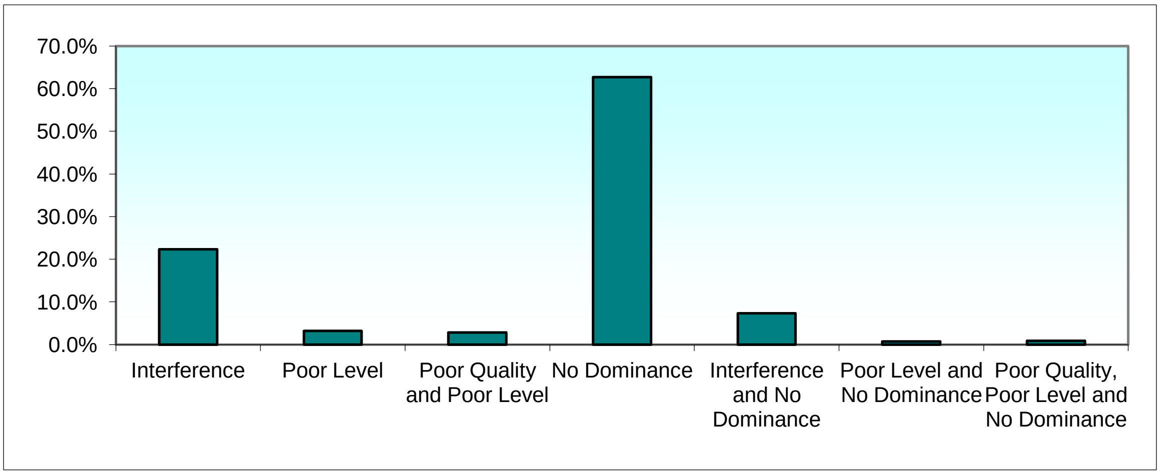


Figure 5.16: Poor Design by classification

Lack of Dominance server can cause signals of more than one cell can be reaching a spot with low level causing ping pong handovers. This might happen because the MS is located on the cell borders and there is no any best server to keep the call.

Table 5.19: Breakdown of poor design by percentage

Cause	Percent
Interference	22.3%
Poor Level	3.2%
Poor Quality and Poor Level	2.8%
No Dominance	62.7%
Interference and No Dominance	7.3%
Poor Level and No Dominance	0.7%
Poor Quality, Poor Level and No Dominance	0.9%

Table 5.20: Poor design causes

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

5.7 Summary

In summary, measurements and analysis for the three mobile operators in Iraq is investigated by looking at the KPI (key Performance Indicator) parameters in a drive test result, measurements are investigated for both events and radio KPIs.

Events KPIs are Drop Call Rate, Call Setup Success Rate, Handover Success Rate, etc. and also radio KPIs are RxLev, RxQual, BER, etc. The measurements show the result doesn't meet the KPI standards of the regulators and there is a need for optimisations and frequents measurements to improve the QoS.

Revising frequency plan strategy in order to improve the quality of service also checking and utilising the frequency reuse by using advanced tools such as AFP (Automatic Frequency Planning) as well as activate adhok FH (Frequency Hopping).
Down tilt and removing the overshooting cells according to TA measurements and modifying power, tilt and heights.

Adding new sites for areas which are suffering from weak coverage problems to enhance the dominancy also need a sites audit interims of physical and logical definitions which includes hardware check (i.e cable losses, VSWR measurements, checking cross feeders issue) and neighbours audit in order to reduce the effect of illogical handovers that may lead to bad quality samples. More sites are needed to improve the coverage of network especially for Korek but also the other two operators. Frequent checking of the power settings for current sites also use of high gain antenna for crowded and open areas.
Adding TMA's (Tower Mounted Amplifiers) for rural and open areas to improve the uplink path.

Activate some features to improve RxQual such as antenna hoping power control. Checking percentage of half rate channels to full rate and trying to increase the latter one. Finally Neighbours audit to remove unnecessary and fake relation and add missing neighbour relation.

Chapter Six

6.0 Measurement Prediction and Simulation

6.1 Coverage Planning

This chapter discusses the coverage footprint for one Iraqi network operator. The coverage measured the Signal level in dBm. Each level has been assign to different colour legend to show how good the level is. Where the power is less than -70dBm there will be very good coverage. If the power is higher than 90dBm there will be loss of coverage and users will suffer from bad connection.

The planning tools used for predication is Nokia NetAct Radio Planner. The received signal statics, drive test and some measurements for model calibration has been discussed.

Finally the coverage predication for many Iraqi cities has been done based on the tool.

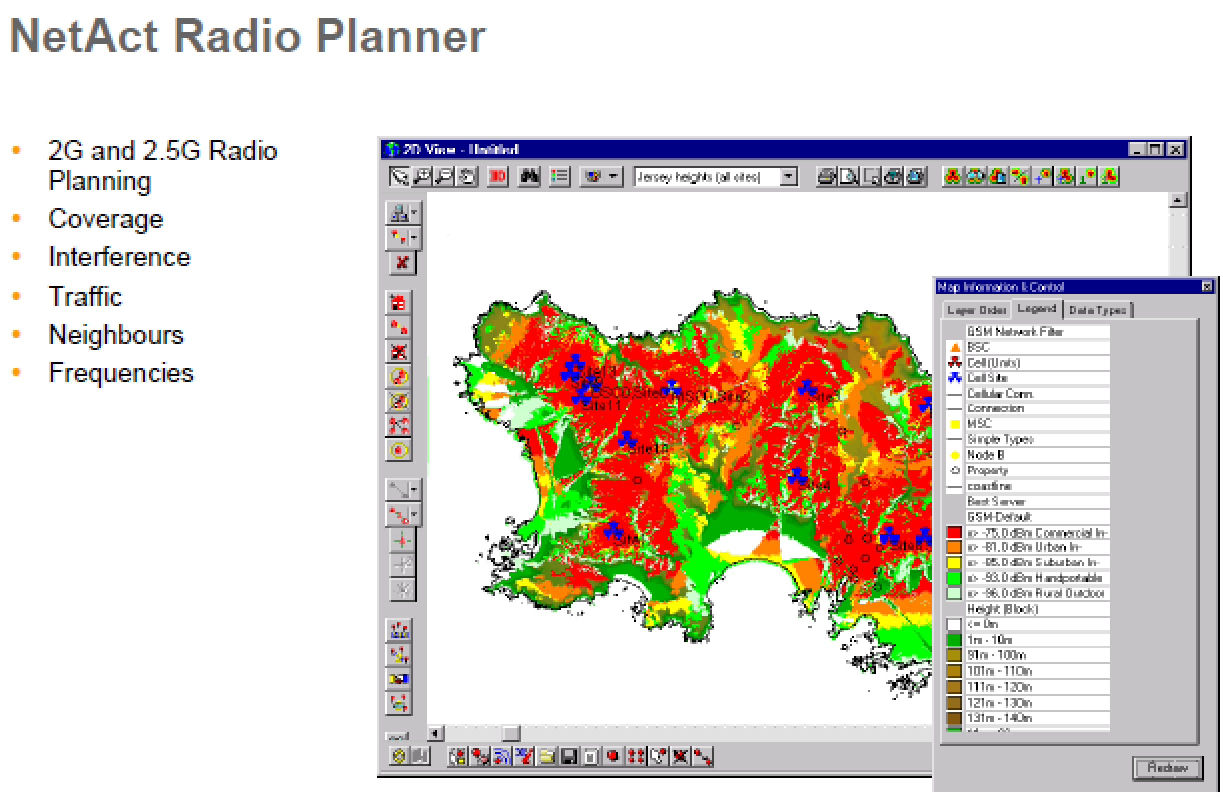


Figure 6.1 – NetAct Radio Planner

Receive Level Statistics

Gives percentage of measurement reports falling into certain

- RxLev interval (can be configured by the operator)
- RxQual value

Low coverage

Example

UL RxLev	q0	q1	q2	q3	q4	q5	q6	q7	total
-100	1	0	0	0	1	1	1	2	6
-95	5	1	1	1	1	1	0	1	11
-90	9	1	1	1	1	1	0	1	16
-80	29	1	0	0	0	0	0	1	31
-70	27	0	0	0	0	0	0	0	27
-37	11	0	0	0	0	0	0	0	11
Total	81	3	2	2	3	3	1	5	

Interference
Bad RxQual in spite of acceptable RxLev

Figure 6.2 – Receive level statistics (1)

Receive Level Statistics

Example

DL RxLev	q0	q1	q2	q3	q4	q5	q6	q7	total
-100	1	0	0	0	0	0	1	0	2
-95	2	0	0	0	0	0	0	0	2
-90	6	0	0	0	0	0	0	0	6
-80	28	1	1	1	1	1	0	0	33
-70	24	1	1	1	0	0	0	0	27
-37	26	0	0	0	0	0	0	0	26
Total	87	2	2	2	1	1	1	0	

Low coverage

Figure 6.3 – Receive Level Statistics (2)

Drive Tests

- Precise location of problems (e.g. coverage holes) possible
- Measurement reports used for statistics give distance with resolution of 550 m only and not any information about the azimuth
- On the other side small region can be examined per time only
- Time dependent problems can escape detection
- Measurement reports allow to monitor all cells of a BSC area simultaneously, so that the interaction of the cells with each other (e.g. interference) can be evaluated

6.2 Coverage measurements

The coverage measurements are based on the received level statics and drive test measurements, which is covered in chapter 5. Finally selections of measurements used for model calibration shown in the below graph.

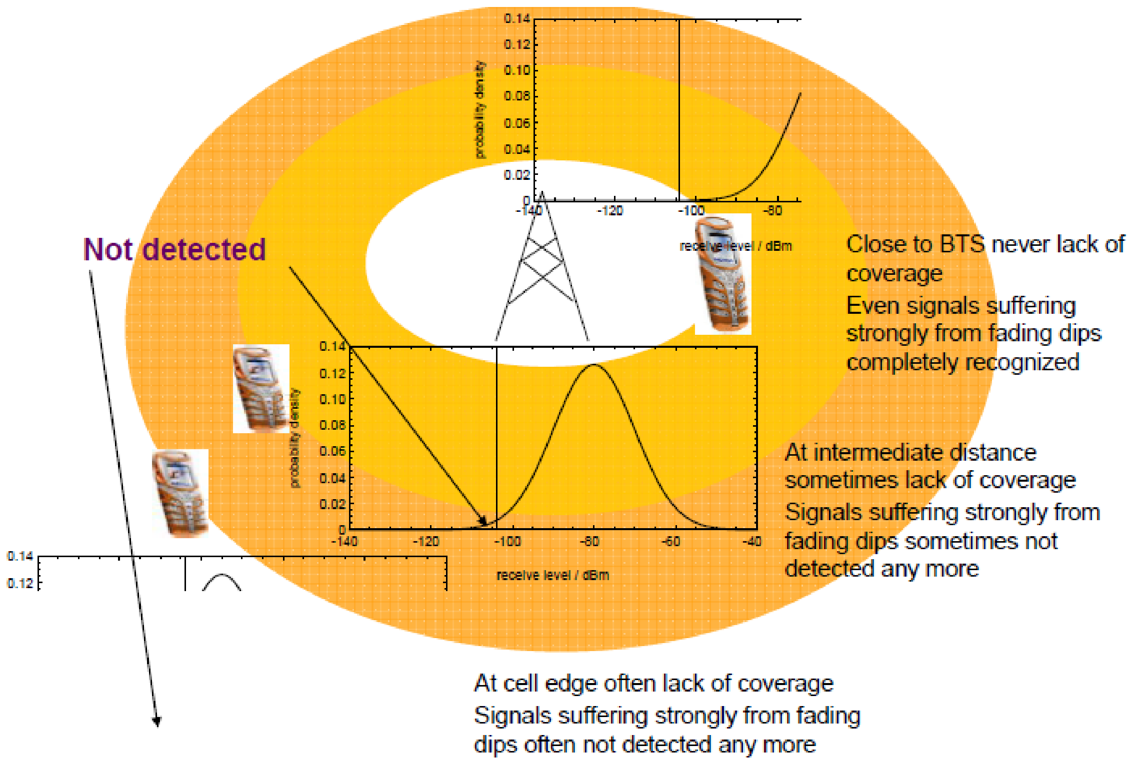


Figure 6.4: Coverage measurement signals strength

The below graph show measurements plot from drive test show the level of received signal and distribution. Majority of the sample are between -90 to -42 which show good level of RX Level.

The DT measurements referenced in chapter 6 is roughly validating the predication measurements in this chapter

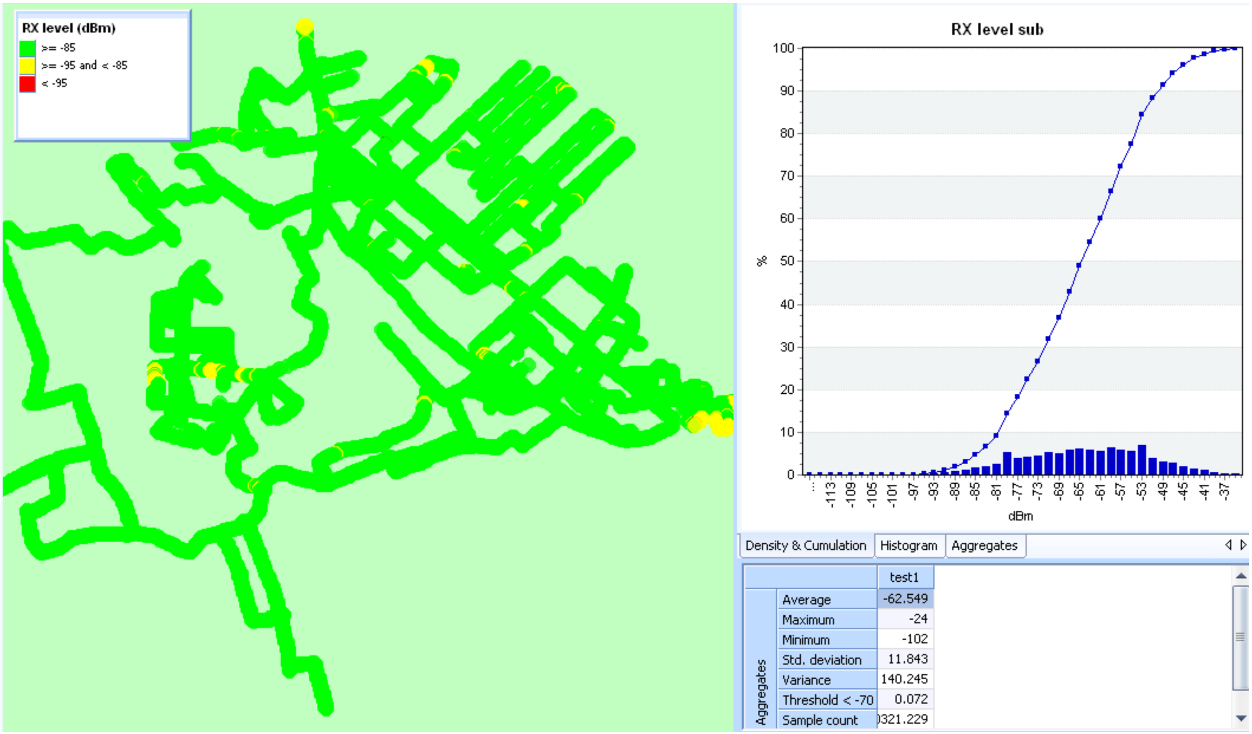


Figure 6.5: Received signal measurement

6.3 Cell Range calculation based on link Budgets.

Path balance implies that the coverage of the downlink is equal to the coverage of the uplink. The power budget shows whether the uplink or the downlink is the weak link. When the downlink is stronger, the EIRP used in the prediction should be based on the balanced BTS output power. When the uplink is stronger, the maximum BTS output power is used instead. Practice indicates that in cases where the downlink is the stronger it is advantageous to have a somewhat (2-3 dB) higher base EIRP than the one strictly calculated from power balance considerations. This is because the diversity gain sometimes exceeds 3.5 dB. In the calculations below the antenna gain in the MS and the MS feeder loss are both zero and therefore omitted. It is also assumed that the antenna gain and the feeder loss are the same for the transmitter and receiver side of the BTS.

Link Budget Parameter

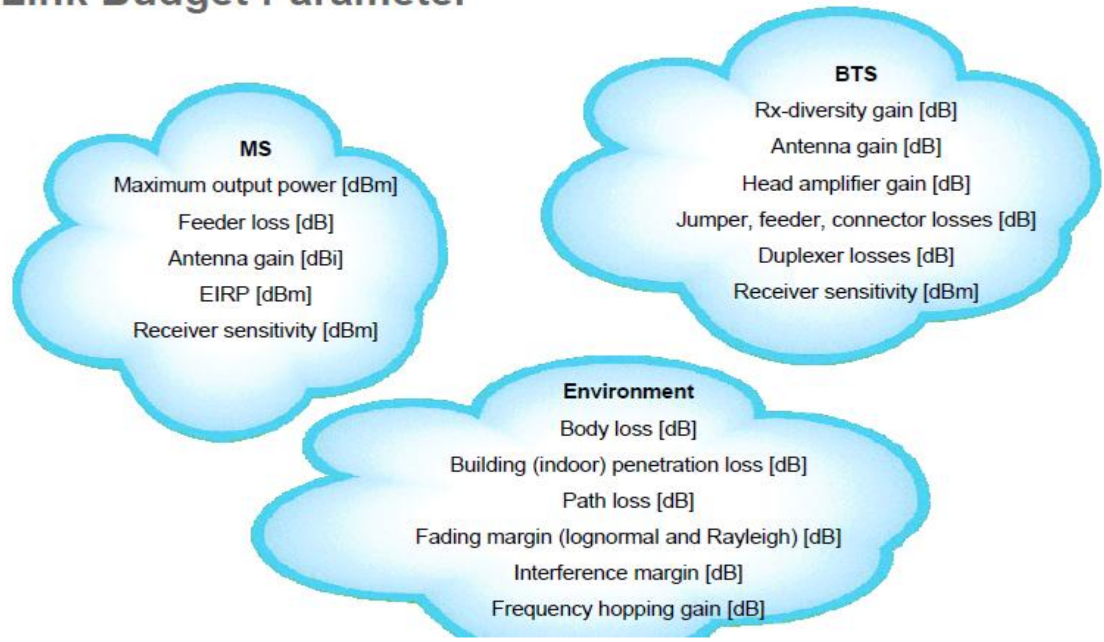


Figure 6.6: Link budget parameter

Summary Cell Types

Cell radius relative to rural sector macro cell (type of highest coverage)
Original Okumura Hata model with previous example values
Clutter correction Rural cell 28.5 dB
Dense urban cell 0 dB

Cell type	$R / R_{\text{rural sector macro}}$
• Rural sector macro	1
• Rural omni macro	0.593
• Rural sector micro	0.427 / 0.555 (DL / UL)
• Rural omni micro	0.253 / 0.329 (DL / UL)
• Dense urban sector macro	0.058
• Dense urban omni macro	0.034
• Dense urban sector micro	0.025 / 0.032 (DL / UL)
• Dense urban omni micro	0.015 / 0.019 (DL / UL)

In dense urban environment macro BTS required to realize even small cells

Table 6.1: Summary cell types

Cell Type and Cell Area

When cell radius is known, the cell area can be calculated
Often traditional hexagon model is considered

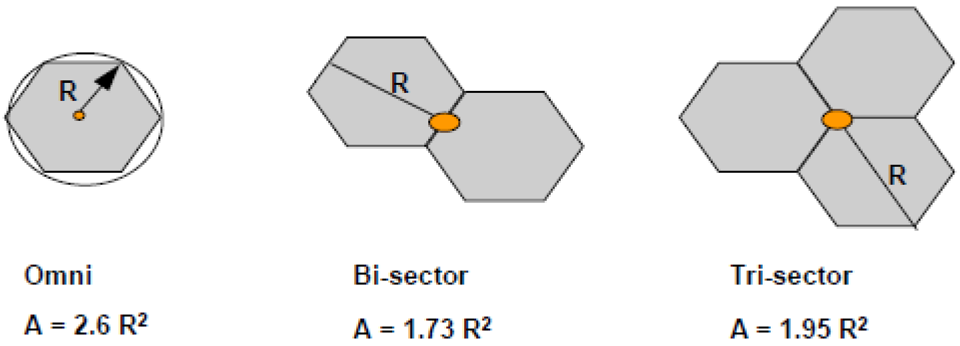


Figure 6.7: Hexagon model

Receiver Sensitivity

The **receiver sensitivity levels** to be fulfilled on UL and DL are defined in GSM 05.05
These depend on the power class of the equipment and the cell type

- BTS requirements
  - Macro BTS -104 dBm
  - GSM 900 micro BTS M1 -97 dBm
  - GSM 900 micro BTS M2 -92 dBm
  - GSM 900 micro BTS M3 -87 dBm
  - DCS 1800 micro BTS M1 -102 dBm
  - DCS 1800 micro BTS M2 -97 dBm
  - DCS 1800 micro BTS M3 -92 dBm
- MS requirements
  - GSM 900 MS class 4-5 -102 dBm
  - GSM 900 MS class 1-3 -104 dBm
  - DCS 1800 MS class 1-2 -100 dBm
  - DCS 1800 MS class 3 MS -102 dBm

Antenna Gain

Related to horizontal and vertical beam width
Narrow beams can be achieved with antenna of large size, especially at high frequency
The usage of antennas with a specific beam width depends mainly on the cell type

Omni cells

- Seldom realized today for macro cells, but frequently for micro cells and always for pico cells
- No horizontal, but vertical energy concentration only
- Small gain of about 5-10 dB in dependence on vertical beam width

Sector cells

- Realized for most macro cells, seldom for micro cells and never for pico cells
- 3 sector site
  - Dominating type
  - Horizontal half power beam width of about 60^0-80^0, considerable gain of about 13-18 dB
- 6 sector site
  - Seldom realized
  - Horizontal half power beam width of about 30^0, high gain of about 16-21 dB

6.4 Coverage snapshot

The coverage predication has been run and simulated for one Iraqi network. First run was for whole country and second time for number of south cities. The following graph shows the signal level across all Iraq cities. The result shows satisfactory level in city centre and some urban area. However most of the suburban is covered poorly. Most of rural area is not covered and required additions of more sites with high towers more 60 meters of highest. The tilts of the antennas must be set to zero degree to have a wider range and cover large distance.

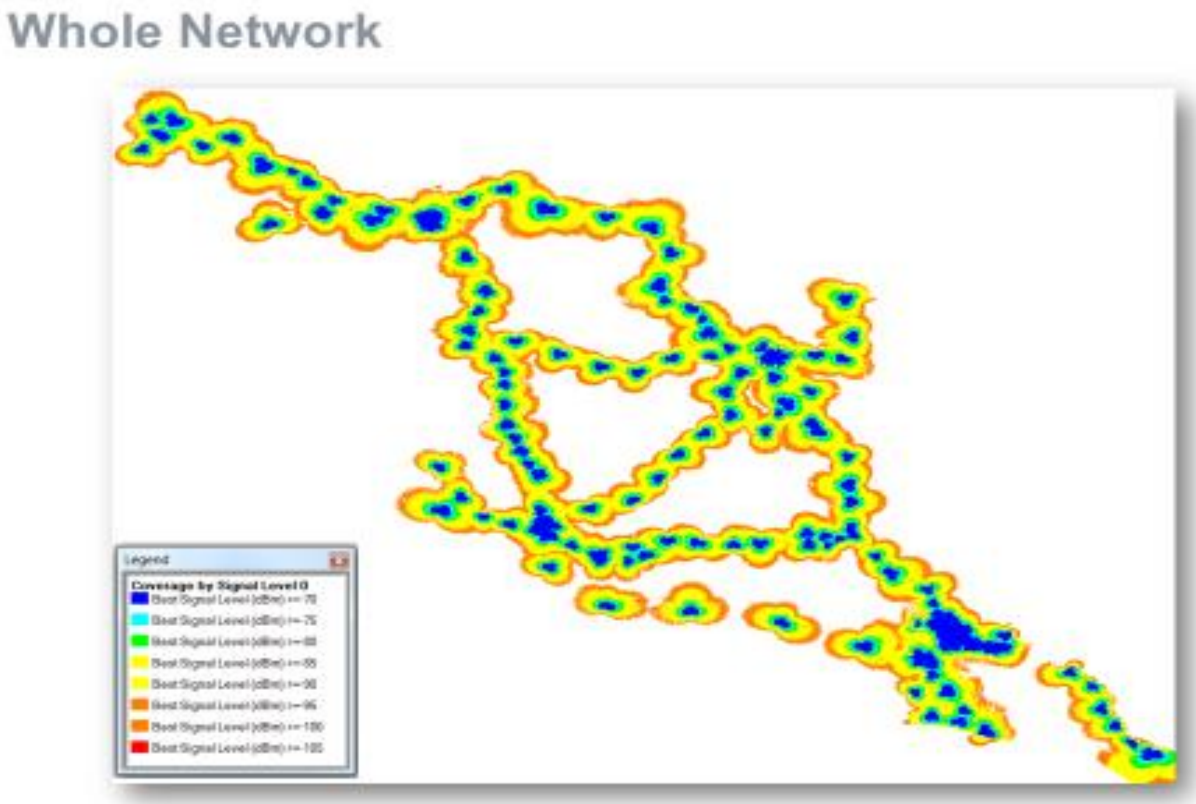
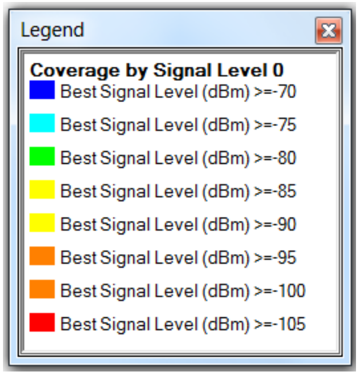


Figure 6.8: Whole network coverage

Basrah Governorate



The following graph shows the signal level in Basrah city. The result show good level in all Basra sub regions. However there is many spots covered poorly. Most of rural area is not covered and required additions of more sites with high towers more 40 meters of highest. The tilts of the antennas must be set to 4 and 6 degree to enable sites serve dense area.

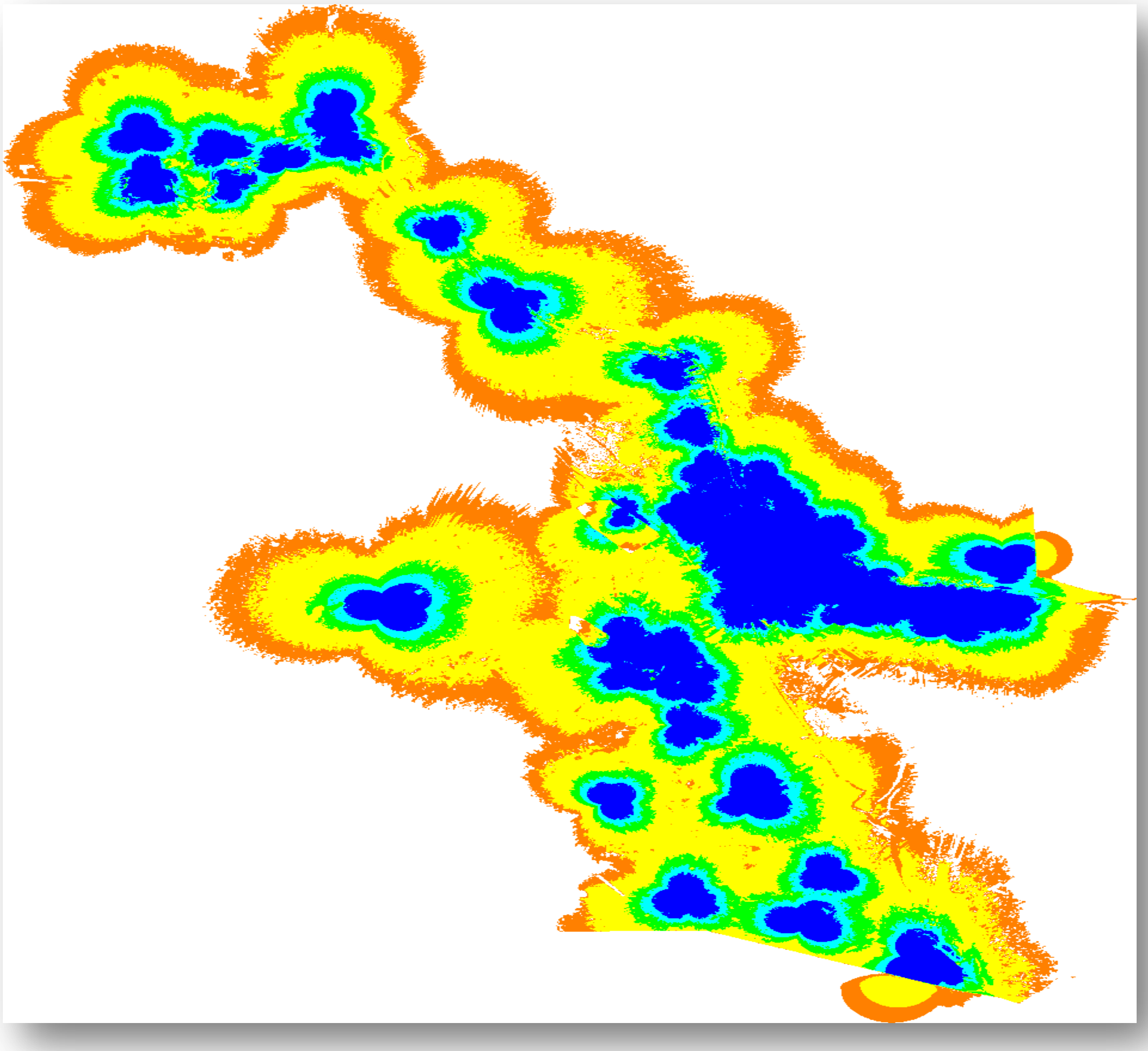
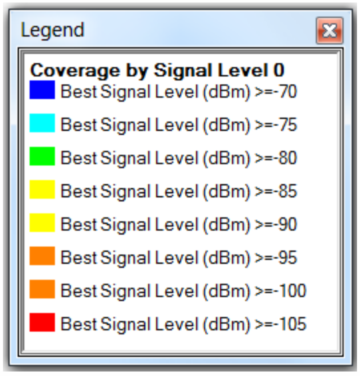


Figure 6.9: Basrah network coverage

Misan Governorate

The following graph shows the signal level in Misan city. The result show good level in all Misan sub regions. There are some rural area is not covered and required additions of more sites with high towers more 40 meters of highest. The tilts of the antennas must be set to 4 and 6 degree to enable sites serve dense area.



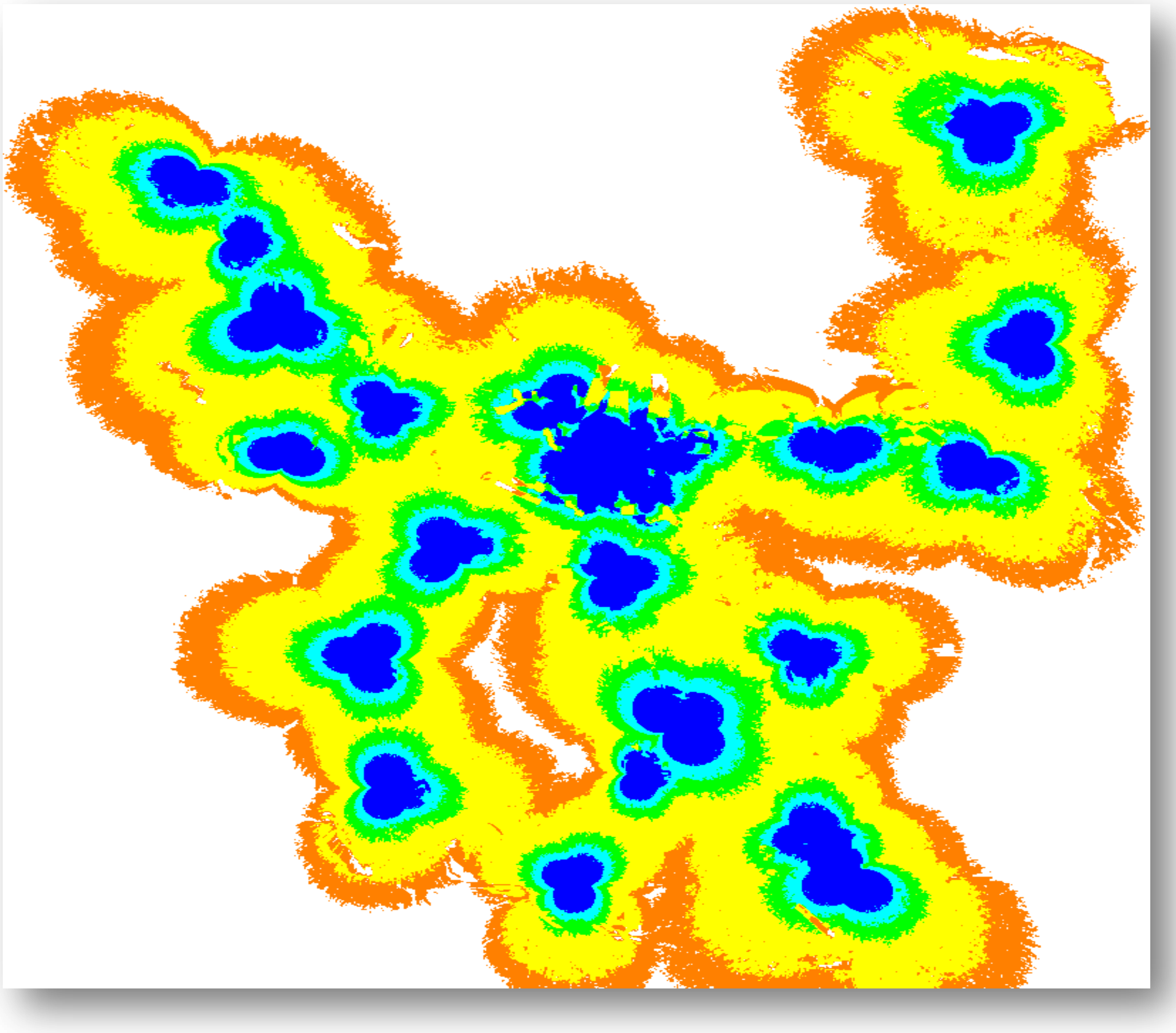
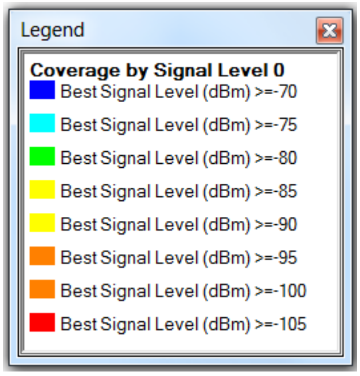


Figure 6.10: Misan network coverage

Thiqar Governorate

The following graph shows the signal level in Thiqar city. The result show good level in all sub regions. All the rural area is not covered and required additions of more sites with high towers more 40 meters of highest. The tilts of the antennas must be set to 0 degree as these area is very big and required strong signal.



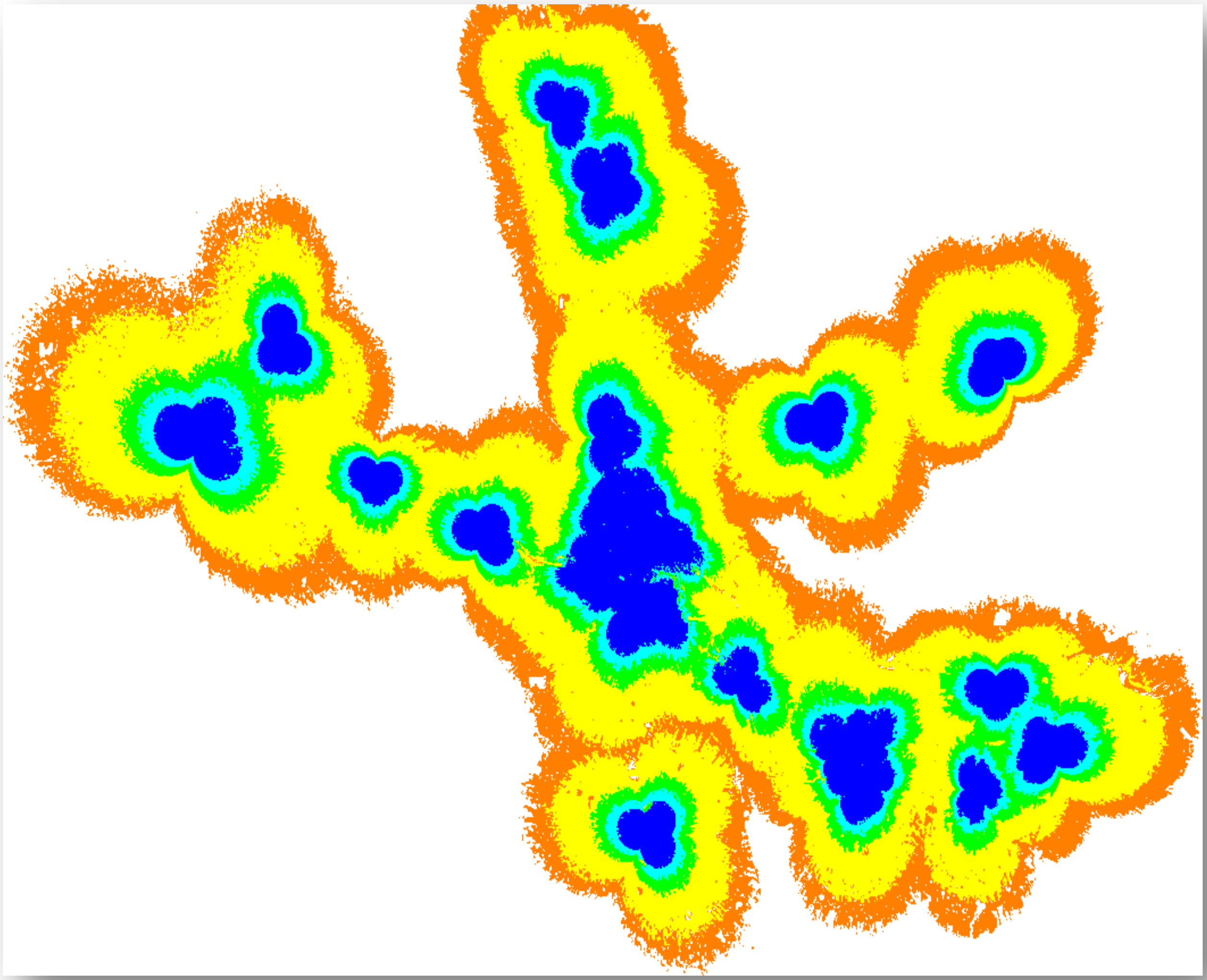
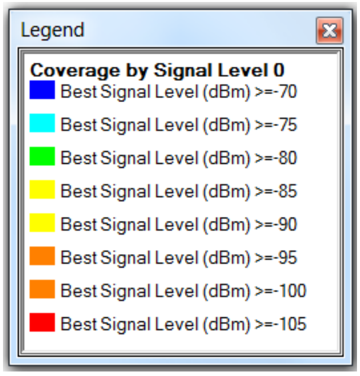


Figure 6.11: Thiqar network coverage

Wasit Governorate

The following graph shows the signal level in Wasit city. The result show good level in city sub. There is some area not covered and required additions of more sites with high towers more 40 meters of highest. The tilts of the antennas must be set to 4 and 6 degree to enable sites serve dense area.



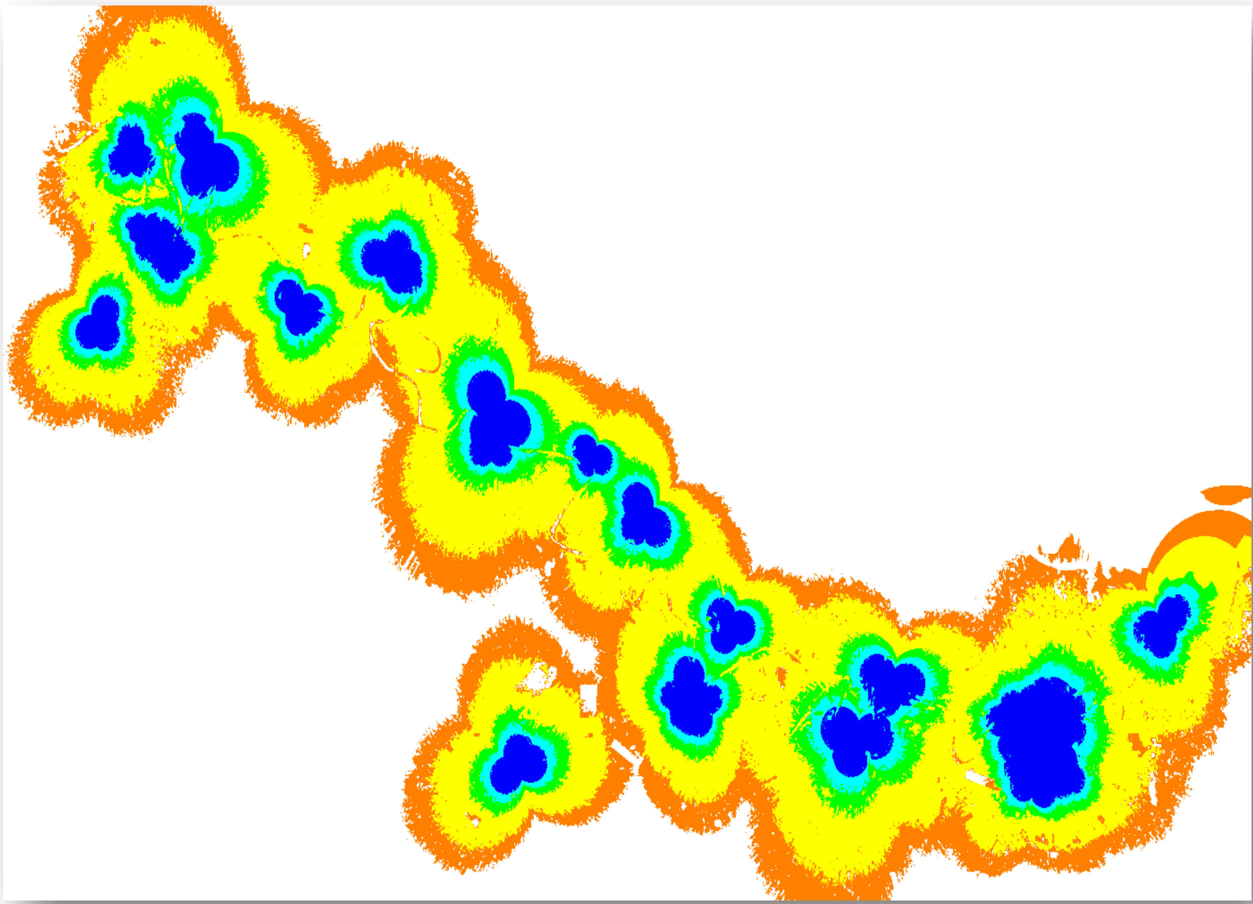


Figure 6.12: Wasit network coverage

6.5 Summary

When planning a system it is not sufficient to use sensitivity level as a planning criterion. Various margins have to be added in order to obtain the desired coverage. In this chapter these margins are discussed and the planning criteria to use in different types of environments are presented.

Furthermore the principles of how to perform coverage prediction are described. The result shows satisfactory level in all Iraqi cities centre and some urban area. However most of the suburban is covered poorly. Most of rural area is not covered and required additions of more sites with high towers more 60 meters of highest. Also it is required to do optimisation work for the radio network and conduct some audit. A physical changes and azimuth changes to cover the poor covered area. The tilts of the antennas must be tuned to have a wider range and cover large distance.

The coverage measurements are based on the received level statics, drive test measurements which is covered in chapter 5. The DT measurements referenced in chapter 5 is roughly validating the predication measurements in this chapter. The following factors need to be considered when comparing DT and predications:

- The predications is a simulations and calculate the RX level for ideal and prefect conditions.
- DT measurements are impacted with many factors compared with predications:
    - Number of users connected to the BTS and occupied the time slots
    - Interference level in the area
    - HW issues exist in the network
    - SW issues which required most of time to reset the BTS

From practical point of view coverage predications have limit usefulness beyond the initial commissioning of a network. In real network operation the predications is overlapped on the same map with DT results to tune the propagation model K factors for better predications.

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Chapter Seven

7.0 Conclusion and Further works

7.1 Conclusion

This thesis addressed the reasons of the decreased Quality Of Service (QoS) caused by interferences in the service providers in Iraq through measurements, and analyses of GSM/CDMA operators.

The deployment of GSM/CDMA system into Iraqi market almost 10 years ago was universally embraced and found to be relatively efficient. With time, operators experienced an unprecedented explosive growth in customer base, which brought huge revenue to both the operators and government through tax and license fee.

As the demand increases for the mobile services, many problems bedevil the sector in the recent past. Some of the problems are: - Instability in power supply, security of infrastructure, Inter-Network connectivity, Network congestion, Call setup failure, Call retention / call drop, interference and bad coverage which has increased the requirements for improving performance and QoS in the network itself.

The key challenges are in the area of improved coverage, Quality of Service (QoS) and performance. This thesis investigated the problems, which causes the bad QoS and way to optimise network performance by measuring, and analysis of the data collected from the three GSM operators in Iraq (Zain, AsiaCell, Korek) as well as CDMA Operators in different Iraqi cities. The key parameters necessary for optimisation were enhanced to improve performance. Various recommendations were made on how to improve on the efficiency of the GSM/CDMA wireless communication network.
Improving the performance of the GSM/CDMA network will results in customers becoming more satisfied with the network quality and the current operators i.e. GSM and CDMA and also an increase in competition.

Having evaluated the parameters that attributed to poor quality of service by the GSM/CDMA operators, the following points are suggested towards improving network performance.

Frequent Drive Test and data gathering from different locations will improve the service and reduce the drop-call by carrying an optimisation consistently with revised parameters. The correctness and reliability of the optimisation methods have been improved. The dropped call rate has been optimised by several methods including frequency re-planning, power control parameters tuning, inter-BTS handover parameters tuning, intra-BTS handover parameters tuning and radio link parameters tuning.

During network replacement, a special attention should be given to the configuration of neighbouring cell relations. This was achieved by ensuring that each cell in the local BTS is configured with neighbouring cells in the neighbouring BTSs and configured as a neighbouring cell of other cells in the neighbouring BTSs. The cells in the BTSs under control of different BSCs must be configured as external neighbouring cells with each other.

Additional BTS (base stations) should be installed across the country for GSM/CDMA operators especially for Korek GSM Operator and ITPC as CDMA operator. This would create room for the network to handle more traffic and better coverage whilst also upgrade and optimise all existing base stations. Doubling the **BTS** means more capacity and more coverage depending on number of TRX installed.

If for any reason a base station is to be taken “offline” either for scheduled maintenance, repairs, upgrades or any failure, etc., all neighbouring base stations should have their communication power levels increased. This will increase their coverage area, thereby reducing congestion and dropped calls.

Neighbours cells and site configurations are important for handover gain and interference reductions and should suggest the best possible neighbours relations, antenna heights and tilts should be suggested by using field measurements.

Based on titling mainly interested in the distance from the tower where the signal have dropped of -3dB from maximum gain, this means 50% reduction in power.

The standard antennas for a three-sector site has a horizontal beamwidth, also referred to as the “half power beam. This means that the gain is 3 dB less at half power than the maximum gain in the 0 direction. The theoretical cell border between the sectors, the gain is suppressed typically 10 dB

Compare the drive test data before and after network replacement: this is effective to solve the coverage problem and can provide valid evidence for coverage decrease. If the customer performs network replacement, the drive test data before network replacement may be unavailable; therefore, identifying the coverage problem becomes more difficult. Drive tests can be performed after network replacement and check the BTS to identify the problems such as reverse connection of the feeder, poor coverage of the antenna, and handover failure. In addition, its important to communicate with the customer that makes the complaints and perform field tests to obtain the first hand data for future comparison.
It is easy to avoid the missing configuration of neighbouring cell relations; however, it is difficult to solve the coverage problem caused by the missing configuration of neighbouring cell relations. Therefore, great care is required in initial data configuration and data should be checked in the case of problems to avoid subsequent ineffective input.

The missing configuration of neighbouring cell relations decreases the handover success rate, increases the call drop rate, and reduces the traffic volume. The BTS coverage seems to decrease; however, the coverage does not actually change.
Monitoring and optimisations is important part of operating and maintaining any mobile networks.

- Increased traffic rises new problems for the operators
- Right KPIs and proper use of the KPIs will help to maintain and improve the performance of mobile networks

The GSM business model is changing from Voice services to data and mobile applications so the competition for subscribers is fierce i.e. not only competing with GSM but with even CDMA and ISP too. Subscribers have more choices than ever before about which wireless service to use. To attract, maintain and move subscribers to high-value services such as data, network operators must provide unprecedented quality of service. Higher quality will be achieved only through fast and accurate network optimisation, arming the operator with:

- Efficient spectrum utilisation to meet capacity demands
- Optimal frequency allocation to ensure good call quality
- Accurate neighbour topologies to ensure smooth handovers and call distribution

The three GSM network operators in Iraq as well as the CDMA Operators must periodically optimise their networks to accommodate traffic growth and performance degradation. Optimisation action after service rollout is to correct the expected errors in network planning and the benefits like improved network capacity, enhanced coverage and quality of service. One of the basic objectives of this research is to ensure and guide the optimiser engineers that the radio parameters should be maintained at their standard thresholds after the optimisation of the network to enhance the network performance.

Finally to improve QoS and Networks performance, there is a need for field measurements which require frequent driving tests also finding the best possible configurations for antenna heights, tilts and parameters setting for all present cells/sectors in the networks and also for any new sites that might be needed to improve coverage specially for Korek and Zain as they are extending the coverage and also swapping the equipment's for the 3G ready networks.

The Operators GSM/CDMA should invest heavily in transmission network development by liaising with the Ministry of Communications i.e. ITPC the only owner of infrastructures and have a proper radio planning. This would ensure increased network resilience, improved bandwidth utilisation and alleviation of capacity bottlenecks in capacity, skilled and well-trained Engineers with advanced tools are needed to perform networks tunings and optimisations.

The result of this thesis indicates that the performance of GSM/CDMA networks operators in Iraq is still a far cry from expectations of the consumers and urgent improvement is needed in specific locations where comparatively large proportions of subscribers have complained. Furthermore, external sources (Multi-Coalition Forces/Iraqi military) are partially the reason behind interference, jamming, higher rate of calls drop and false ringing, as well as bad design and planning.

7.2 Further Works

This thesis mainly investigated the QoS performance of voice QoS GSM/CDMA operators. Even though all objectives of this thesis were achieved, this thesis opens doors for further research in the area of wireless networks performance and measurement of QoS for GSM, CDMA, WiMax and LTE in Iraq.

Drive Tests need to be used to verify the actual condition of RF signal for certain operators at certain places but also there are several functions of drive test that are required:

- Analysing customer complaint of certain operator in their home or office area
- Finding problem in BTS (Time slot Check, TRX Check, Swap Feeder)
- Analysing the result of optimisation process (continuity and all of area)

Also measurements and analysis of voice, video and data services with various QoS requirement of CDMA/GSM operators can be investigated to gather further insight from user perspective or drive test.

Furthermore, a cost-efficient analytic tool can accurately evaluate the performance and used for drive tests. TEMS Investigation (Ericsson), ZTE and Huwaie Vendors Tools which were used in this research but also we can use different tools like NEMO-Nokia.

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Appendices

Appendix A: Zakho city CDMA network DT measurement analysis

Base Station Distribution Diagram

Figure 1-1: Distribution map of Huawei base stations in ZakhoCity

In Zakho City, we have 7 CDMA 1X Sites. These sites were:

1- School Site.

2- Factory Site.

3- PTT1 Site.

4- PTT2 Site

5- Border Site.

6- Swimming Site.

7- Tabi Site.

Test Instruments

The tools used in this test are:

PANORAMA series drive test devices and background analysis software

GARMIN GPS

Common Huawei terminal

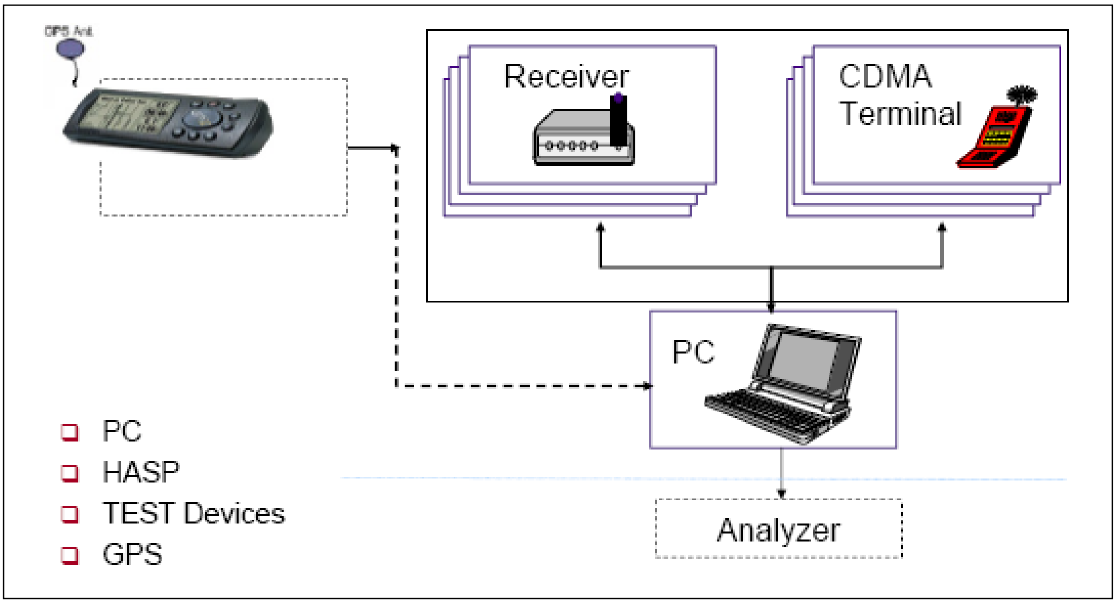


Figure 1-2: Drive test system configuration

1 Drive Test Result and Analysis

1.1 Classification of Network Voice Test Indices

The test and evaluation of the network performance is mainly conducted in combination with the following indices:

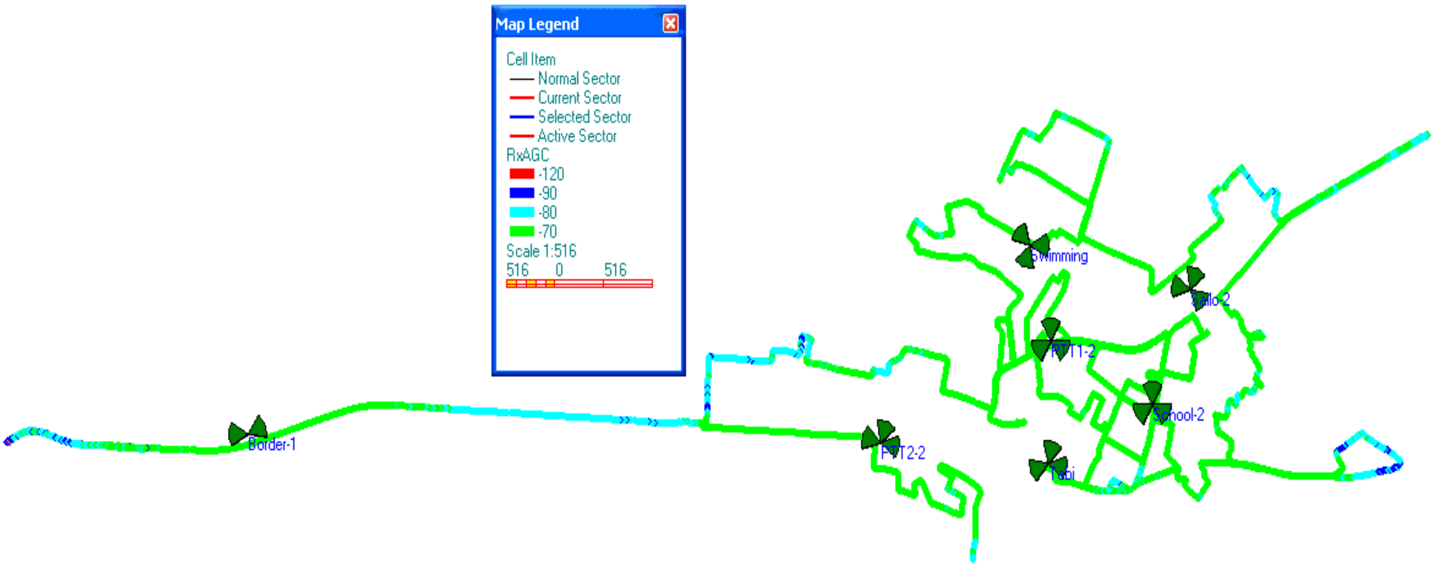
Whole-network **Rx** distribution and statistics;
Whole-network **Ec/Io** distribution and statistics;
Whole-network **TX** distribution and statistics;
Whole-network **FER** distribution and statistics;
Whole-network **Handoff** distribution and statistics;

1.2 Analysis of Drive Test Result

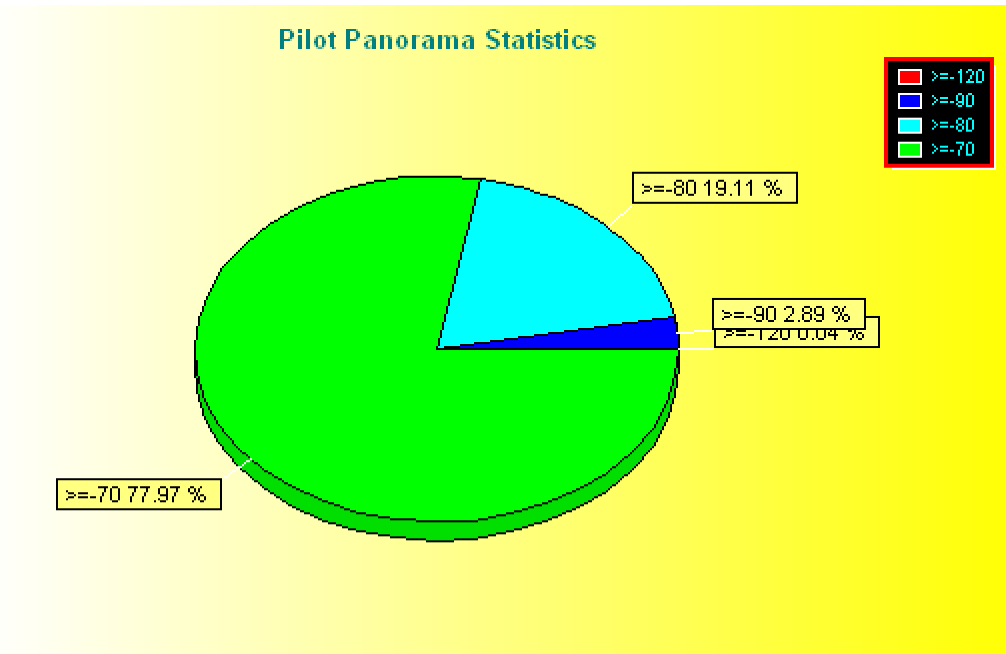
In order to know about the coverage of the network, we make a simple testing in outdoor.

1.2.1 **Whole-network Rx distribution and statistics**

Whole-network Rx distribution



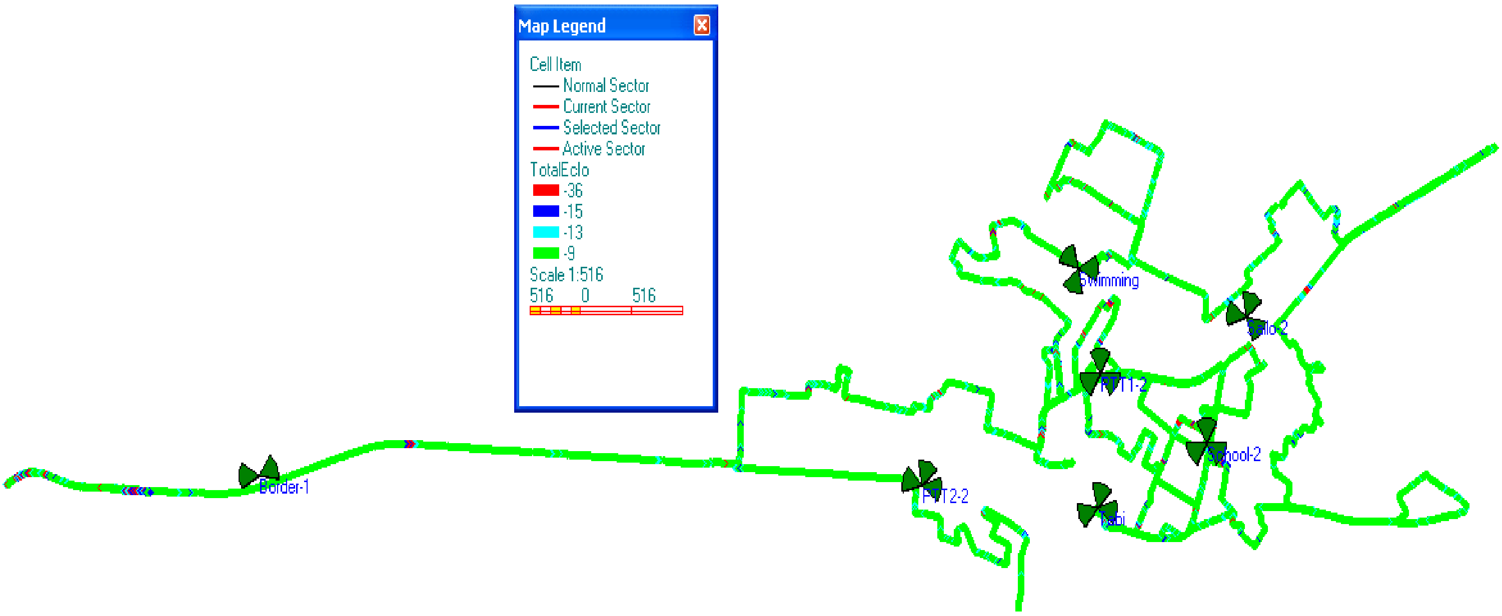
Whole-network Rxstatistics



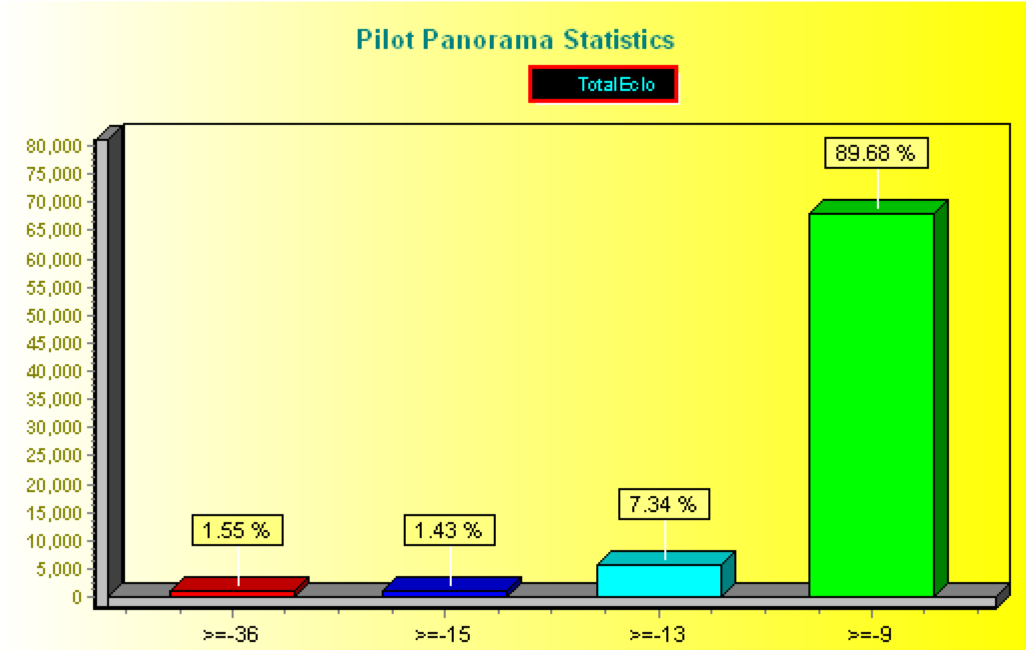
The areas of good Rx level are 77.97 & 19.11% so totally are 97.08 % of the total tested area. This is good ratio.

1.2.2 **Whole-network Ec/Io distribution and statistics**

Whole-network Ec/Io distribution



Whole-network Ec/Iostatistics

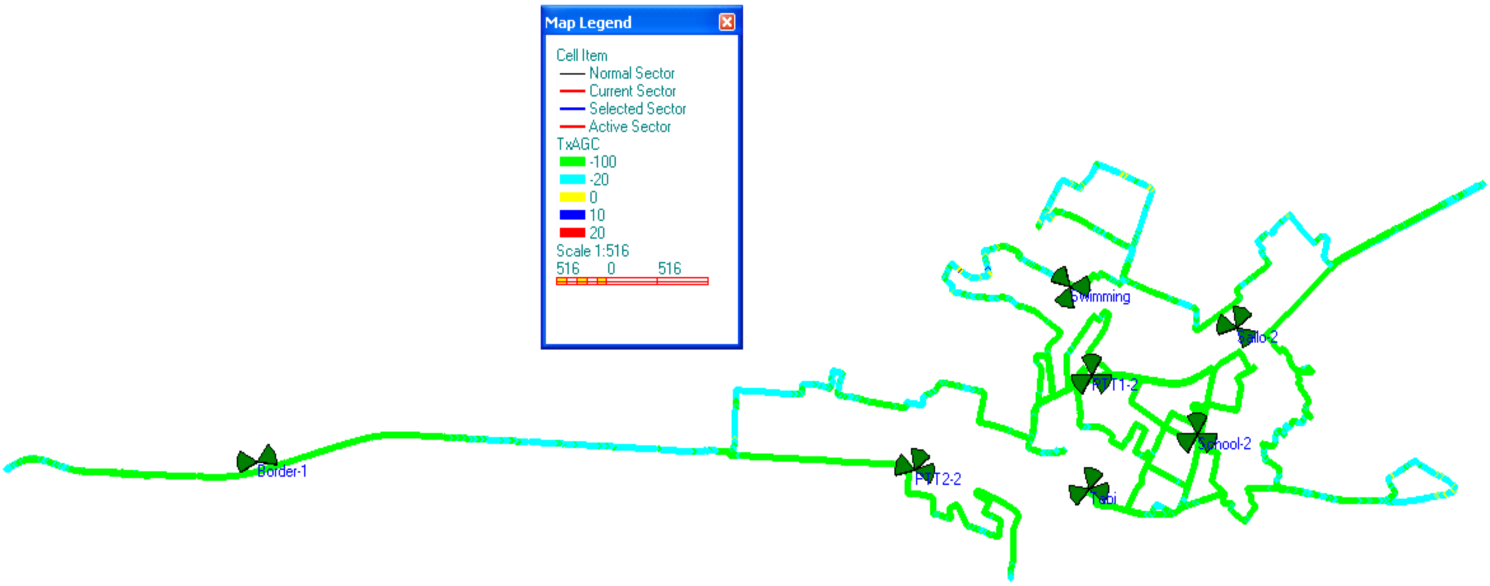


For the network, Ec/Io>= -9 is 89.68% and Ec/Io>= -13 is 7.34% of the tested areas.

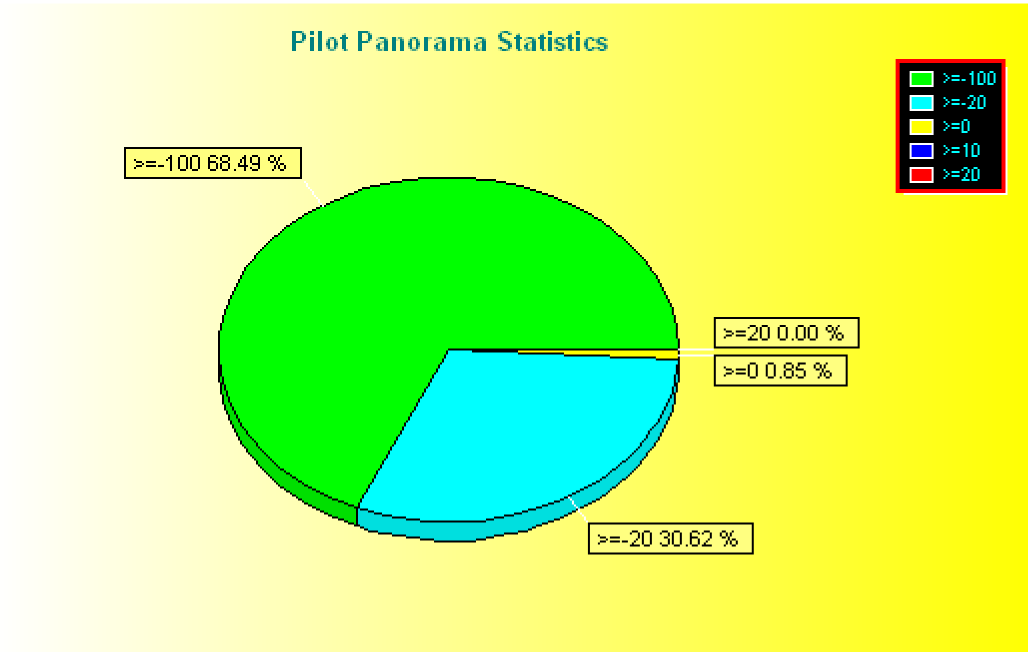
This is also good ratio for normal communication.

1.2.3 **Whole-network Tx distribution and statistics**

Whole-network Tx distribution



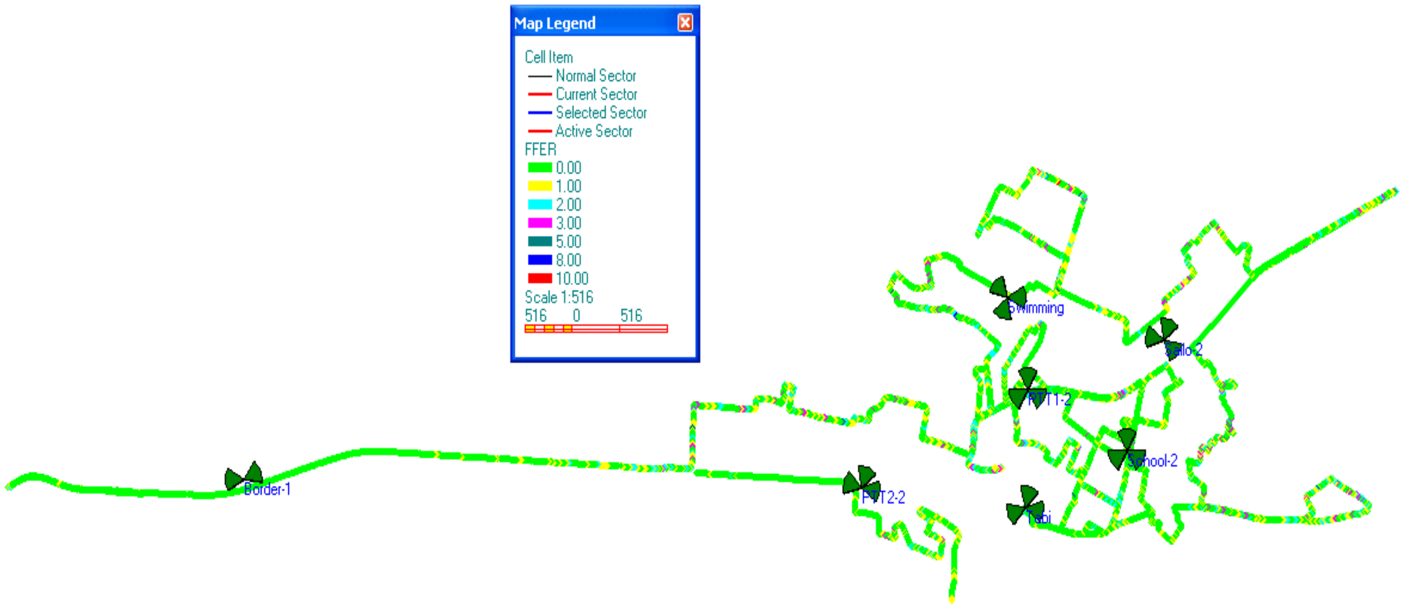
Whole-network Txstatistics



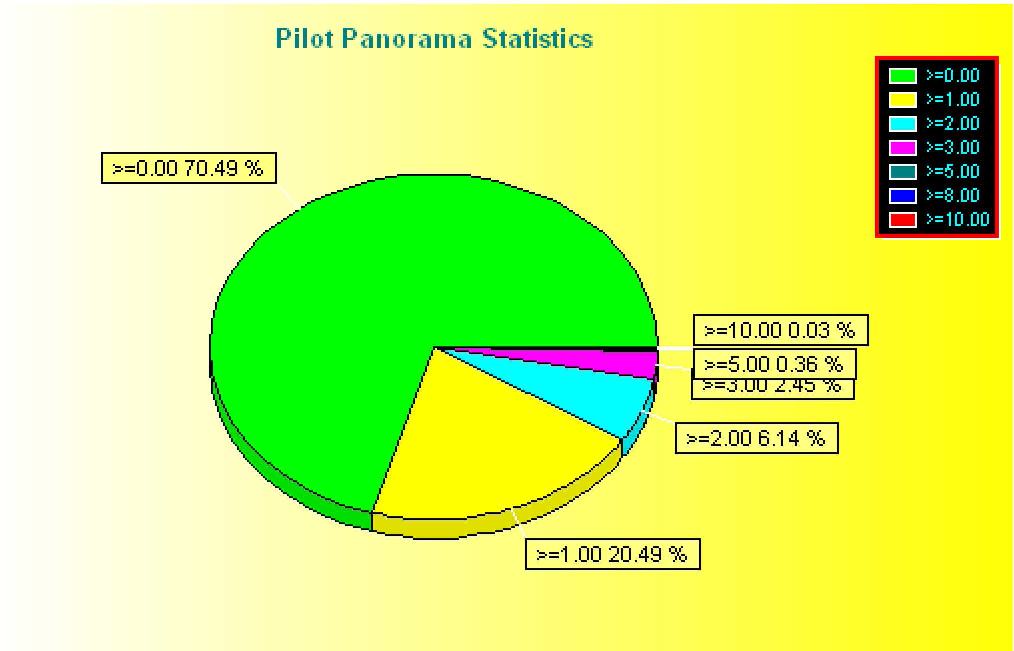
The Tx is good. That is the MS in 99.11 % of the tested area transmit power less than -20dBm.

1.2.4 **Whole-network FER distribution and statistics**

Whole-network FER distribution



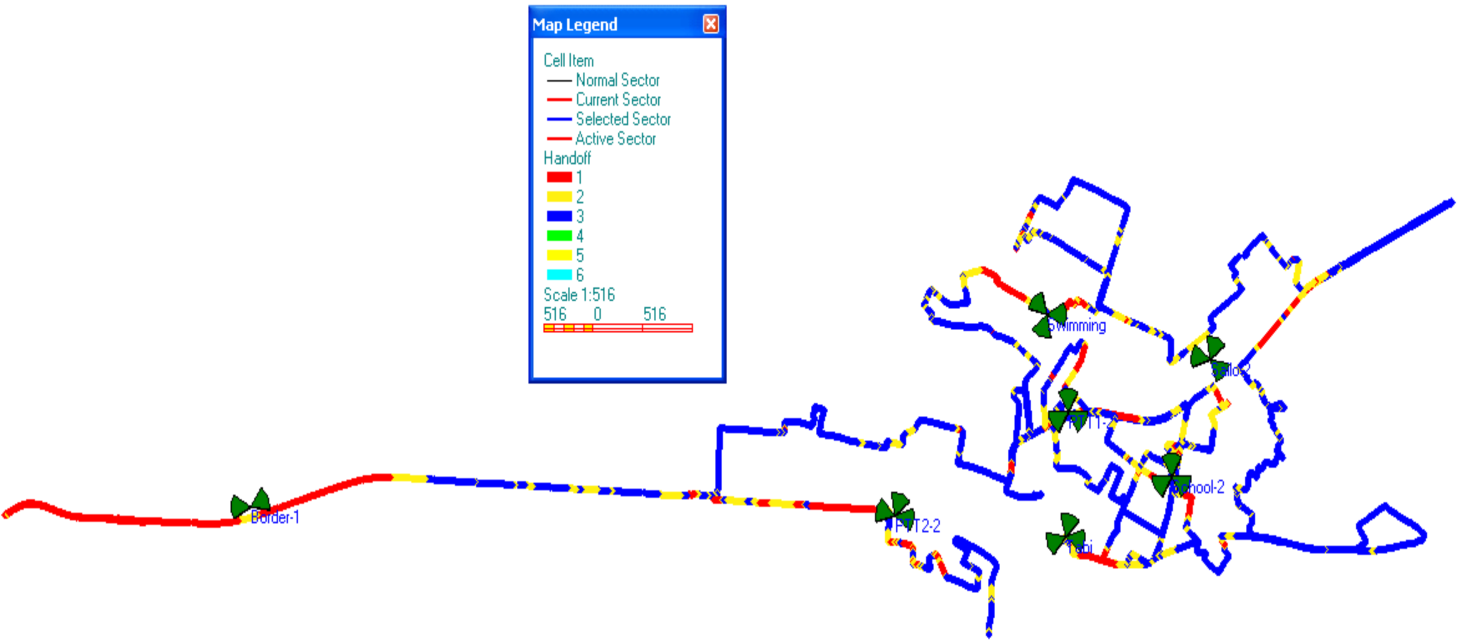
Whole-network FERstatistics



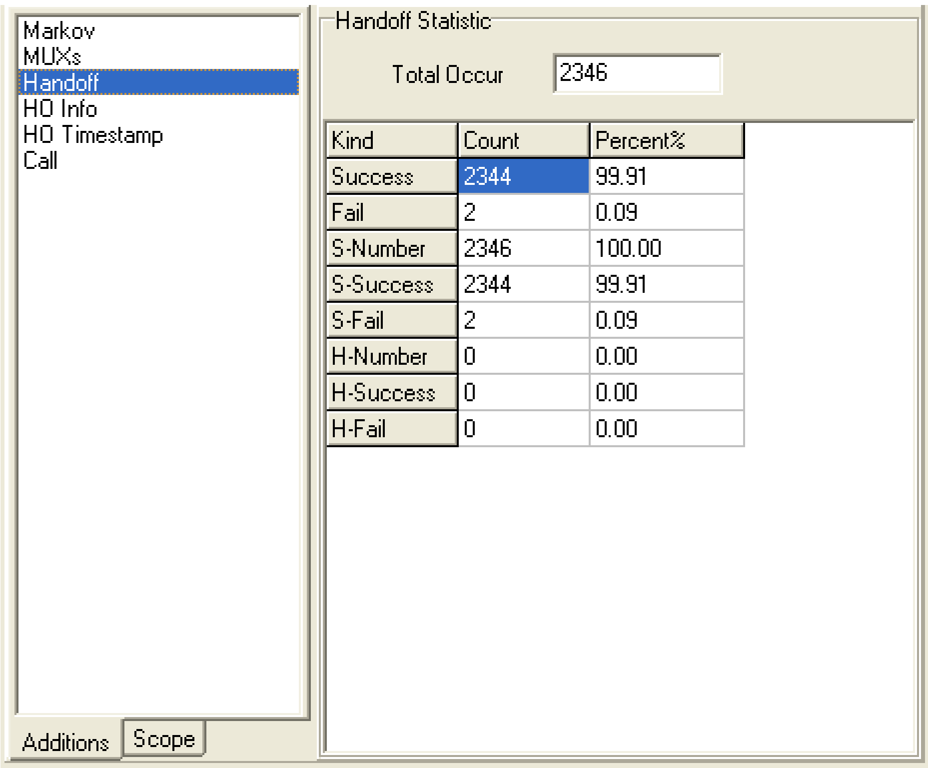
The areas that have FFER less than 3 are 97.12 % of the total tested area.

1.2.5 **Whole-network Handoff distribution and statistics**

Whole-network Handoff distribution



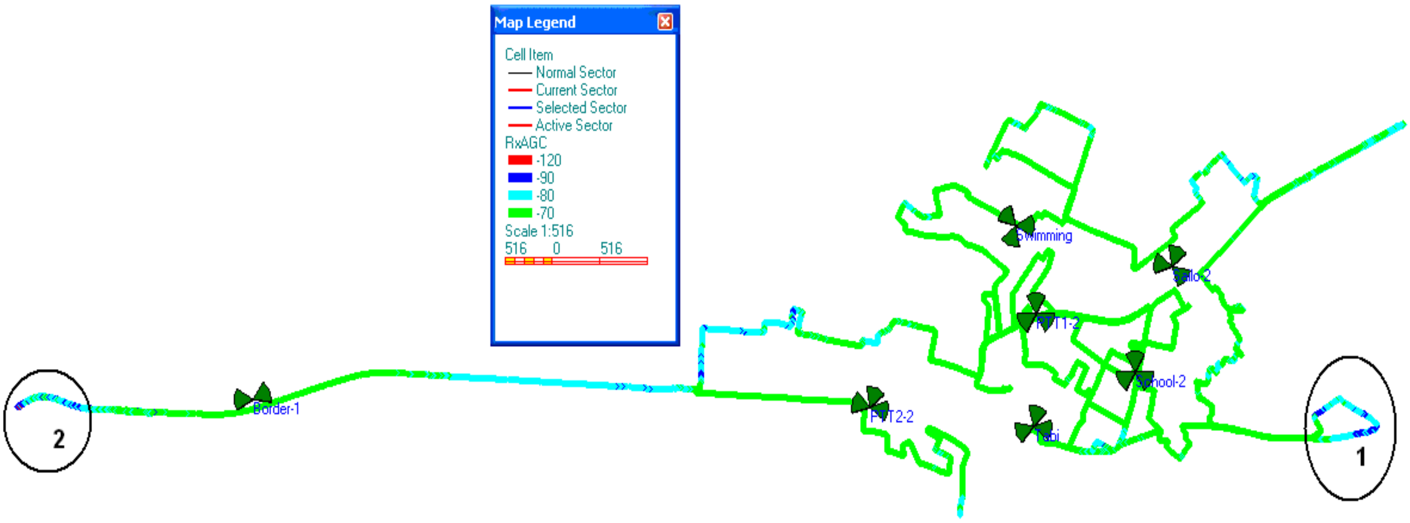
Whole-network Handoff statistics



Kind	Count	Percent%
Success	2344	99.91
Fail	2	0.09
S-Number	2346	100.00
S-Success	2344	99.91
S-Fail	2	0.09
H-Number	0	0.00
H-Success	0	0.00
H-Fail	0	0.00

The HO success ratio is 99.91. Good ratio for good service with minimum call drops.

2 Conclusion and suggestion



From the above Rx Map we can see that Area1 and Area2 have some problems.

For Area 1: This area is much higher than the neighbour sites, and there is little number of houses in this area, we thing even by changing the antenna tilt of school or factory the signal can not enhanced too much.

For Area 2: The suggestion to change Border-1 Azimuth 10 degree CCW.

<u>**Appendix B: Duhok city CDMA network DT measurement analysis**</u>

Base Station Distribution Diagram

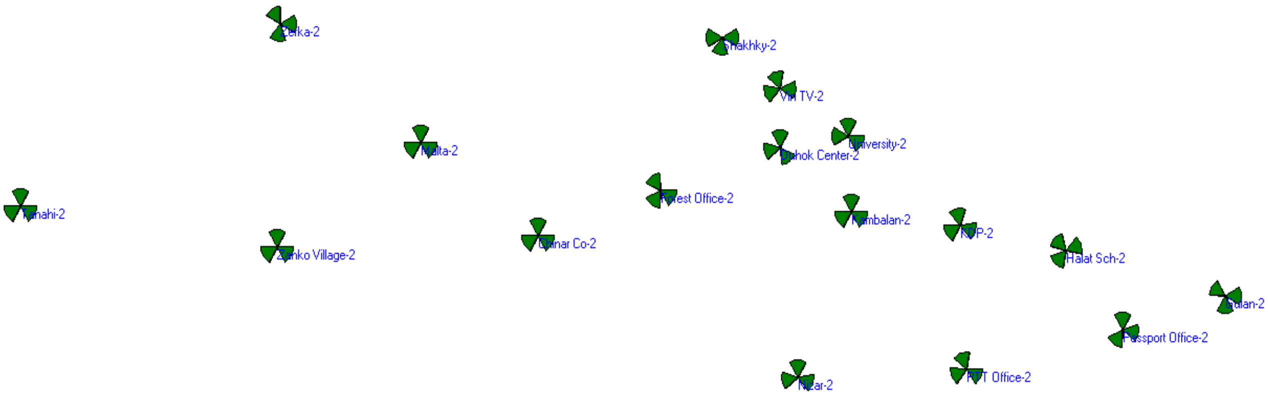


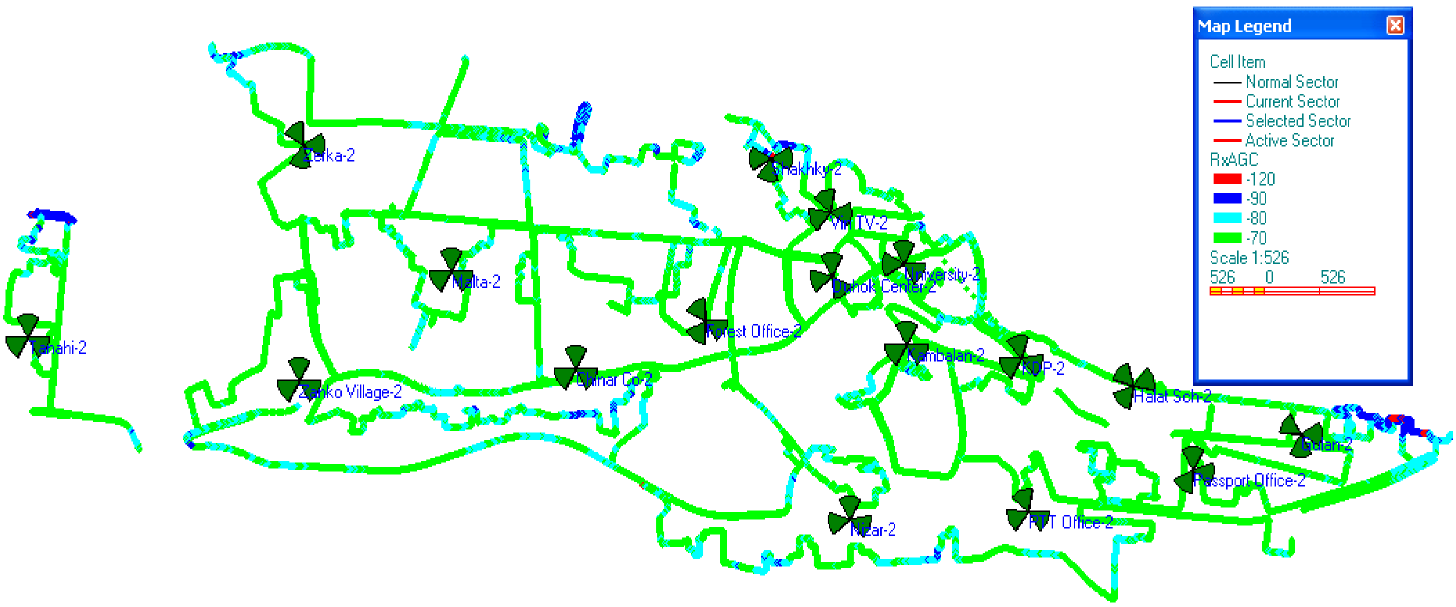
Figure 1-1: Distribution map of Huawei base stations in DuhokCity

In Duhok city, totally we have 19 CDMA 1X Sites.

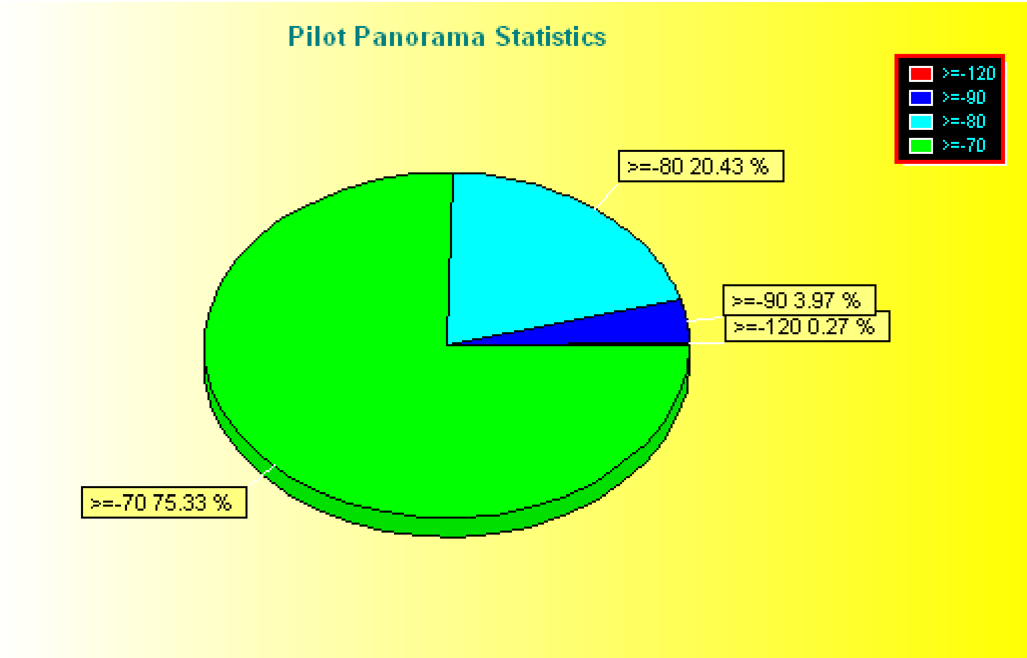
3 Drive Test Result and Analysis

3.1.1 Whole-network Rxdistribution and statistics

Whole-network Rxdistribution



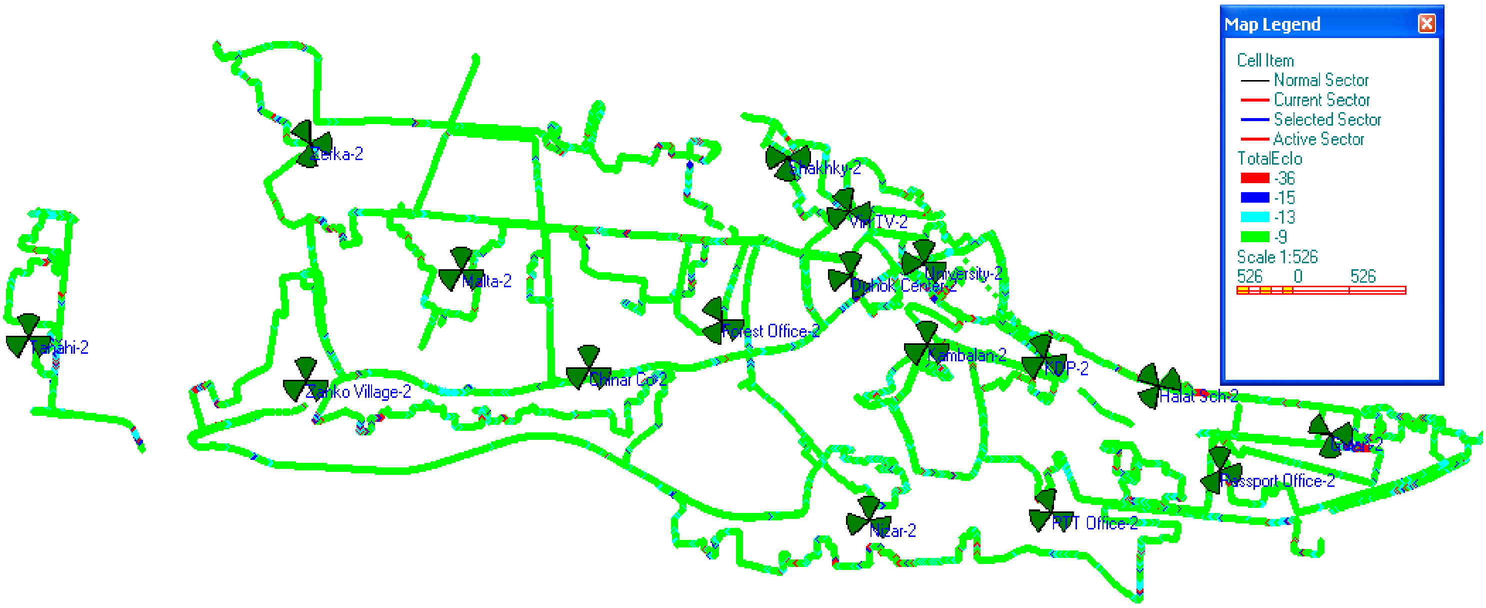
Whole-network Rxstatistics



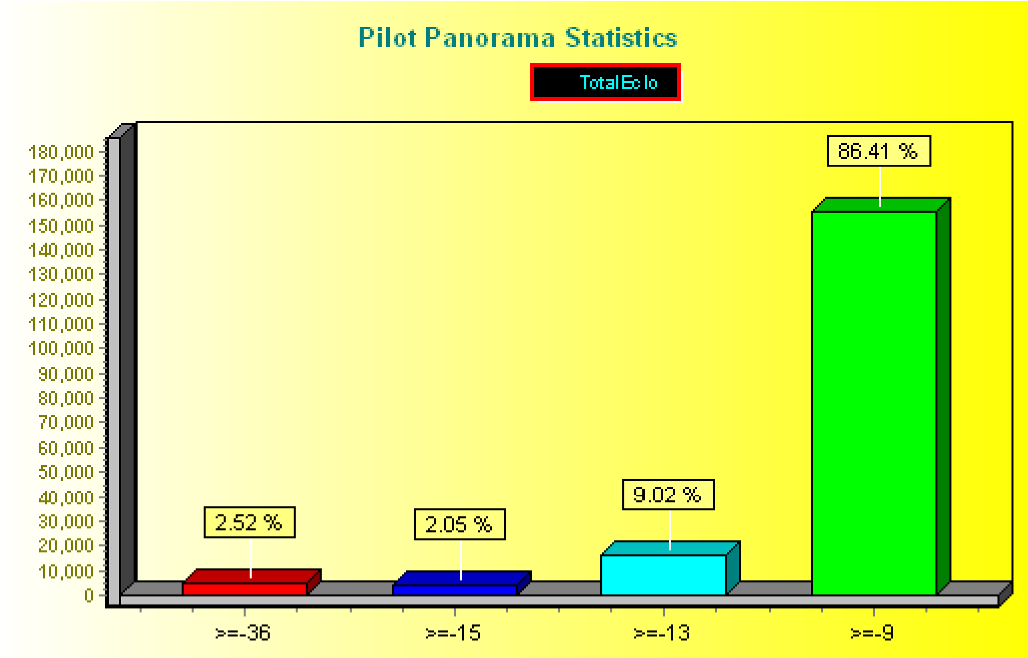
The areas of good Rx level are 75.33% & 20.43% so totally are 95.76% of the total tested area. This is good ratio. But we have some areas with coverage problem.

3.1.2 Whole-network Ec/Iodistribution and statistics

Whole-network Ec/Io distribution



Whole-network Ec/Iostatistics

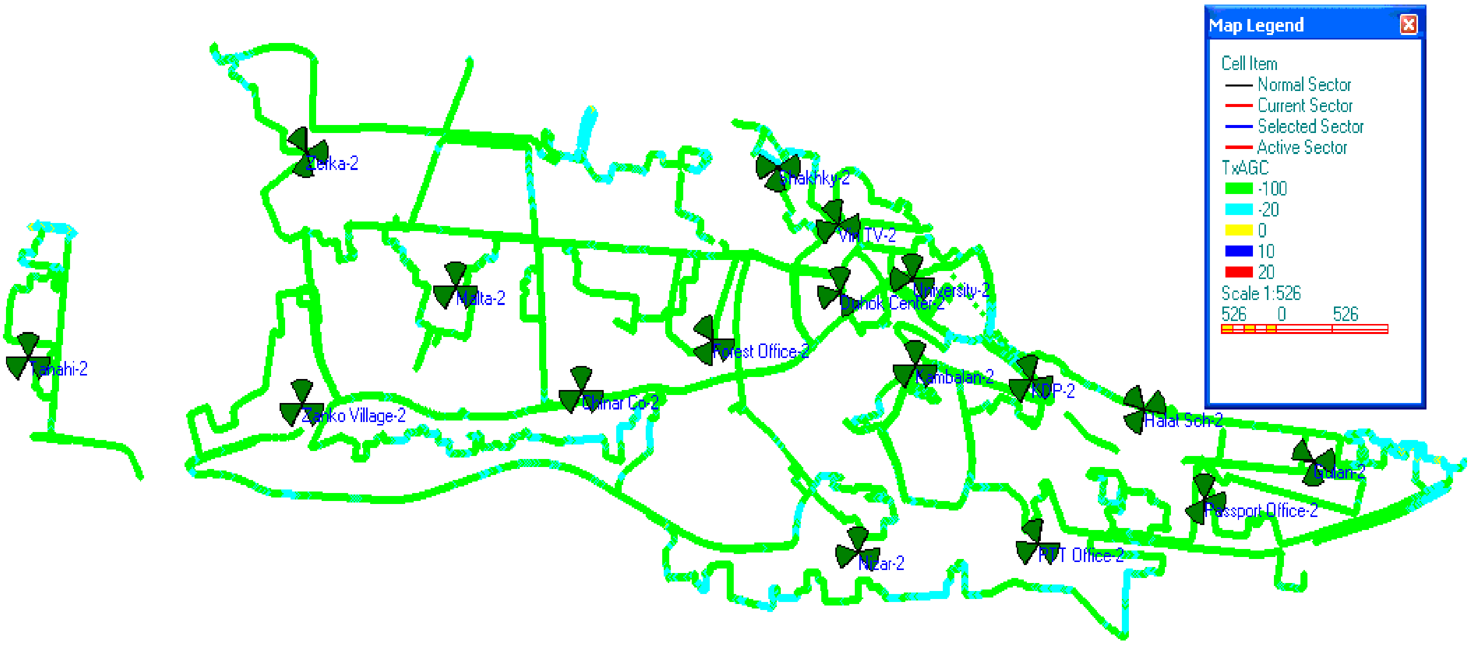


For the network, Ec/Io>= -9 is 86.41% and Ec/Io>= -13 is 9.02% of the tested areas.

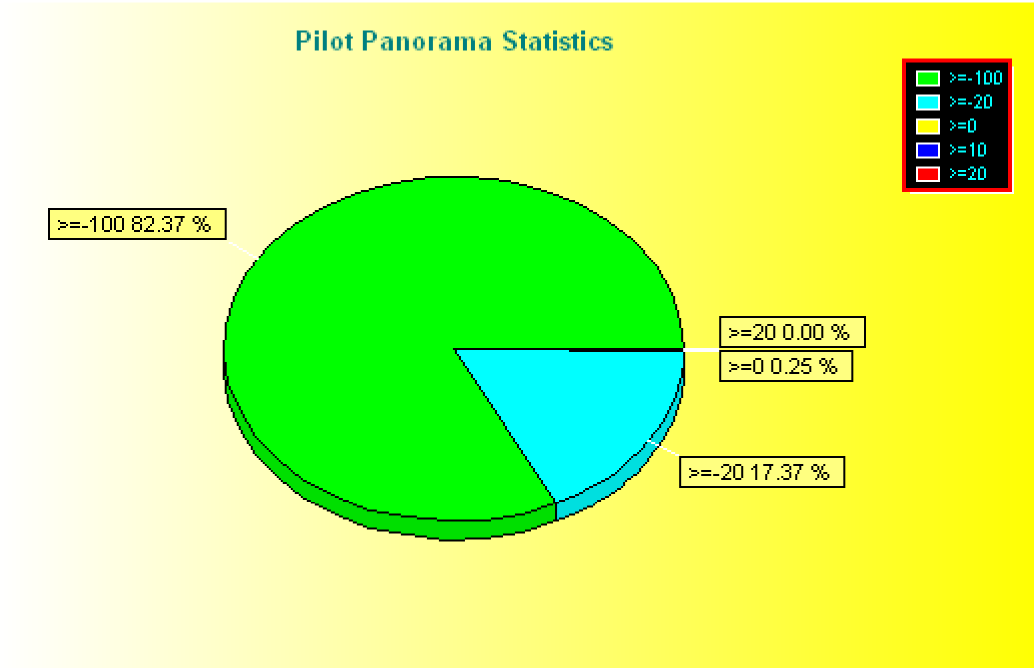
This is also an acceptable ratio.

3.1.3 **Whole-network Tx distribution and statistics**

Whole-network Tx distribution



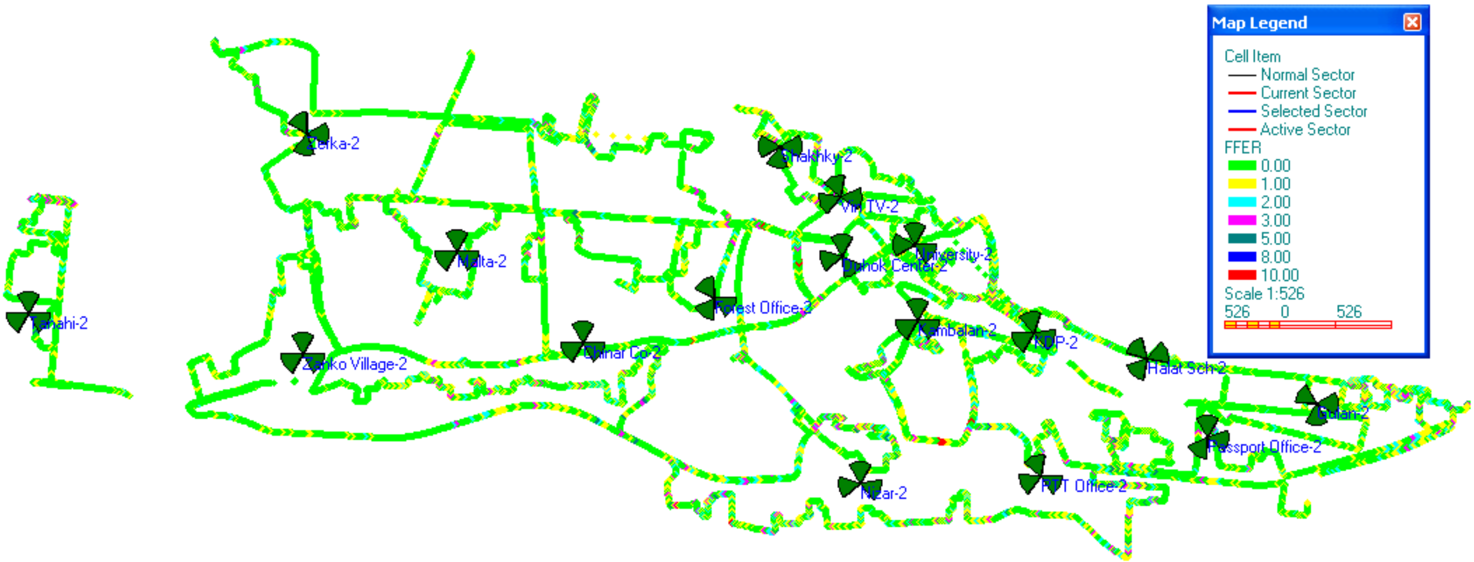
Whole-network Txstatistics



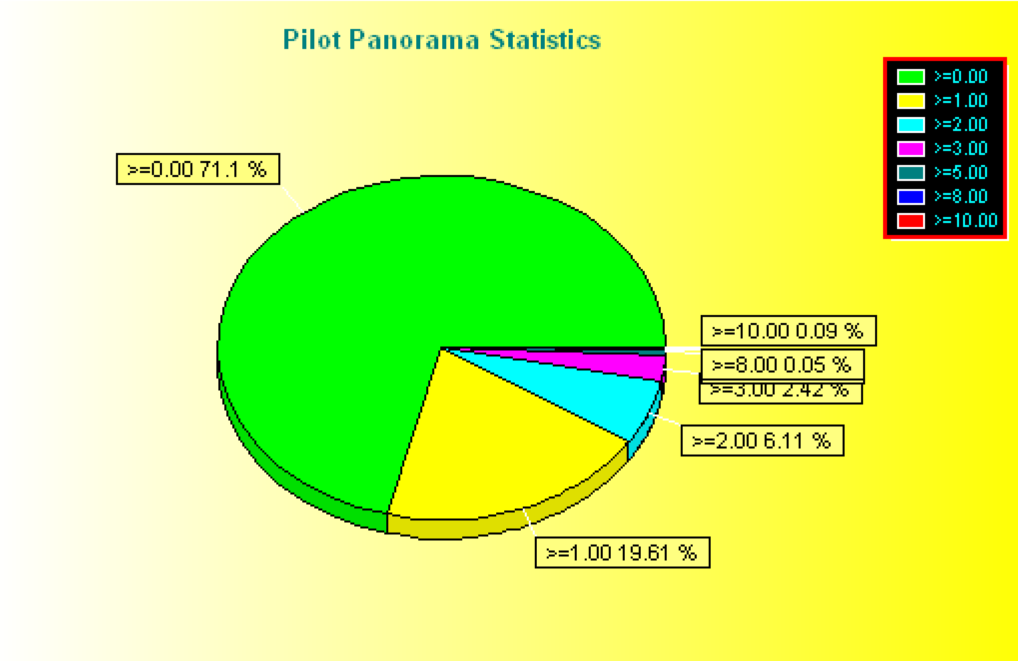
The Tx is good. That is the MS in 99.74% of the tested area transmit power less than -20dBm.

3.1.4 Whole-network FER distribution and statistics

Whole-network FER distribution



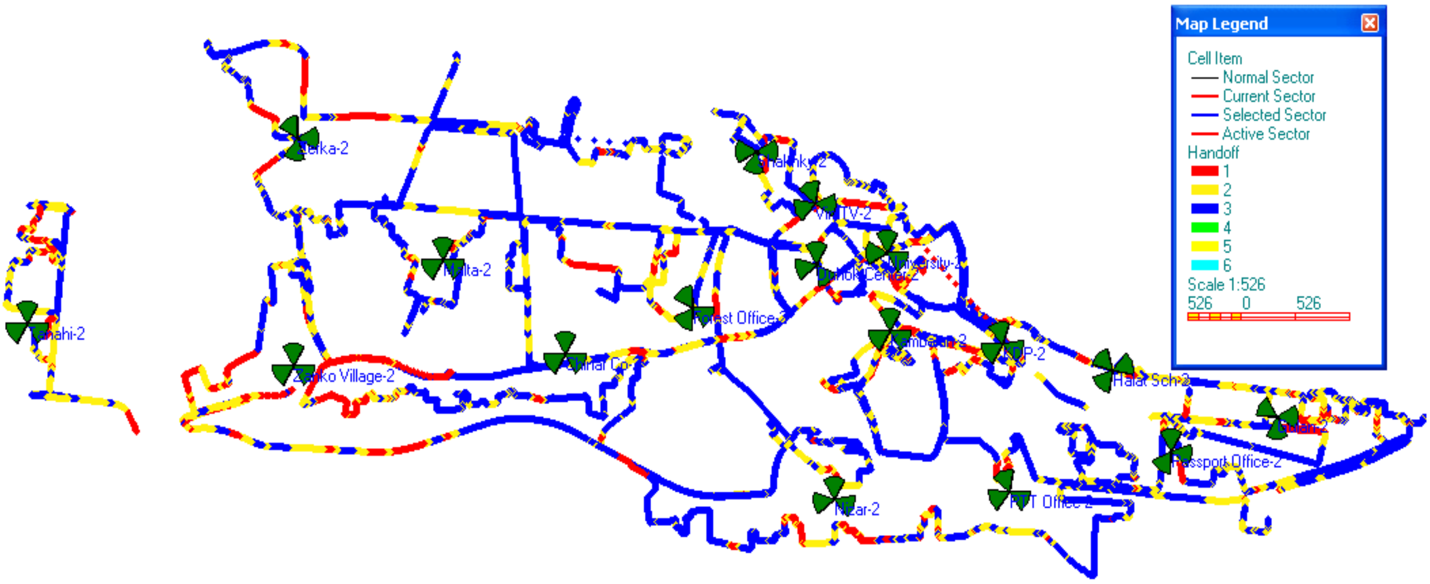
Whole-network FERstatistics



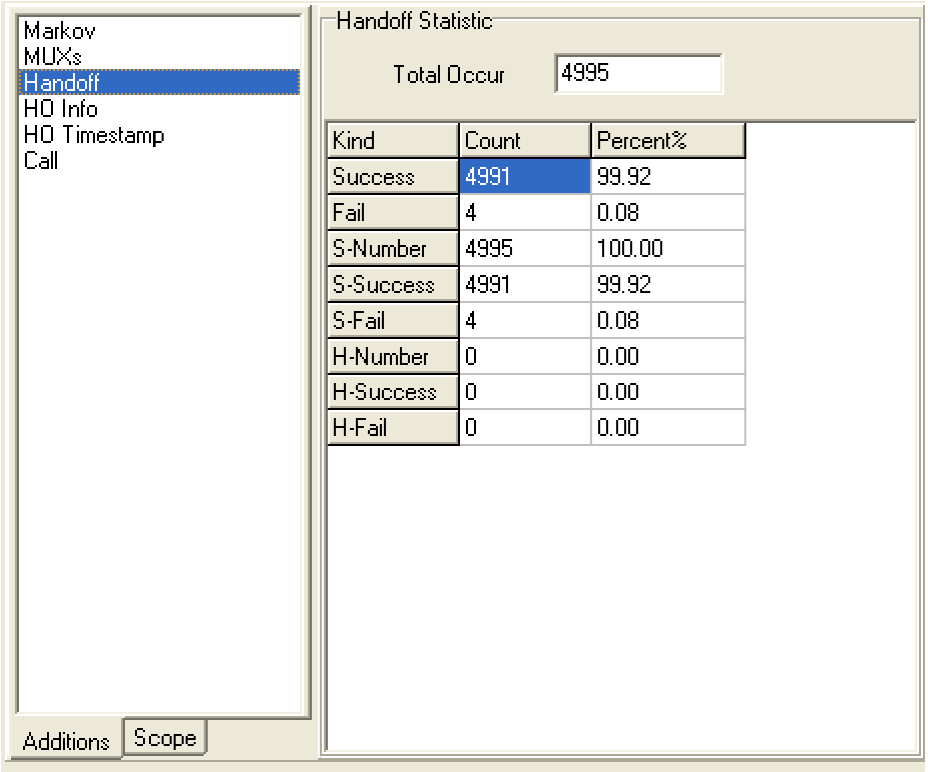
The areas that have FFER less than 3 are 96.82% of the total tested area.

3.1.5 **Whole-network Handoff distribution and statistics**

Whole-network Handoff distribution



Whole-network Handoff statistics

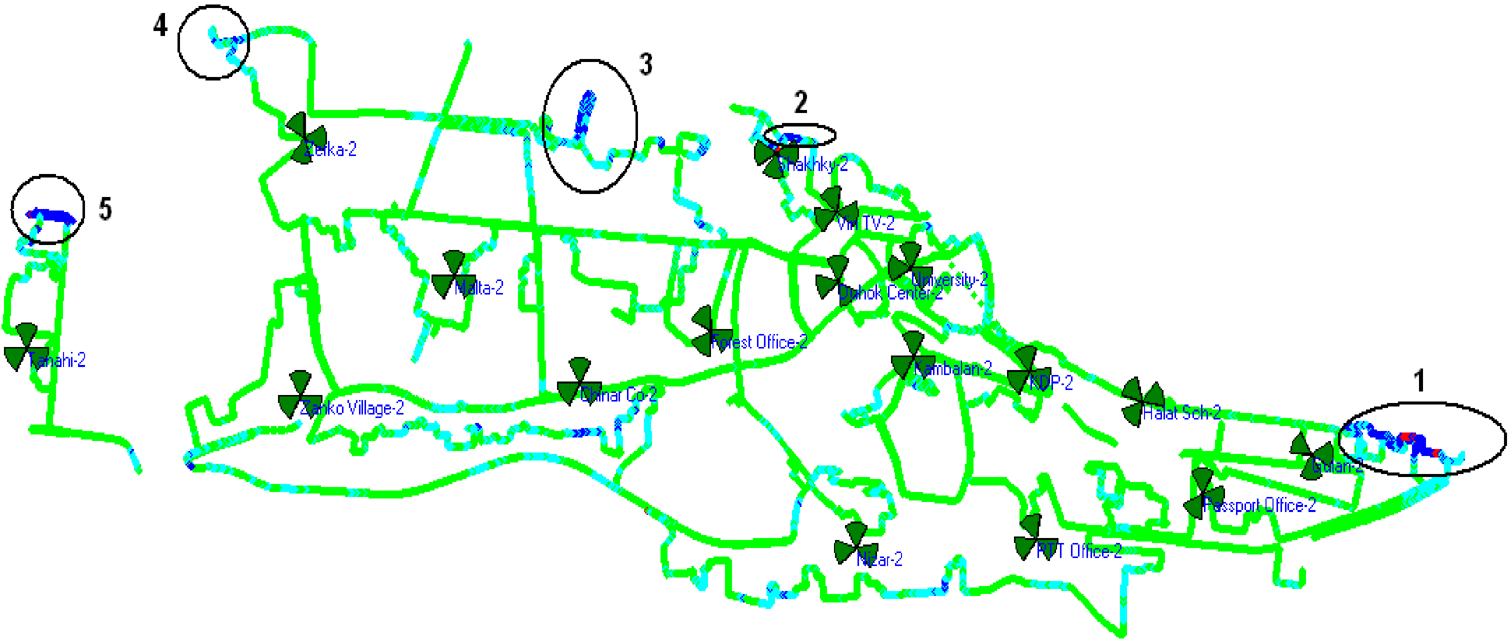


Kind	Count	Percent%
Success	4991	99.92
Fail	4	0.08
S-Number	4995	100.00
S-Success	4991	99.92
S-Fail	4	0.08
H-Number	0	0.00
H-Success	0	0.00
H-Fail	0	0.00

The HO success ratio is 99.92%. Good ratio for good service and minimum call drops.

4 Conclusion and suggestion

The Rx level for all the network is good but from the bellow Rx map we can see that some areas have coverage problem as following:



Area 1: this area is higher than Gulan-1 and to enhance the coverage in this area. The operators have to change the Antenna Down Tilt of Gulan-1 to 0.

Area 2: This area also higher than VINTV-0, so we recommend changing VINTV-0 Down Tilt to 0.

Area 3: this area should receive good signal form Chinar-0, but actually there is a camp contains many high building between Chinar-0 and this area. So the operators will have to change the Malta-0 Azimuth angle from 0 to 30.

Area 4: for this area we recommend in changing Zerka-0 Down Tilt to 2.

Area 5: Tanahi Site is installed on area lower than this area. So for this site we recommend to change tilt of Tanahi-0 to 0.

Appendix C: Erbil city CDMA network DT measurement analysis

Base Station Distribution Diagram

There are 39 CDMA2000 1X sites in Erbil city, 31 of these sites are inside the city and 8 sites are outside the city.

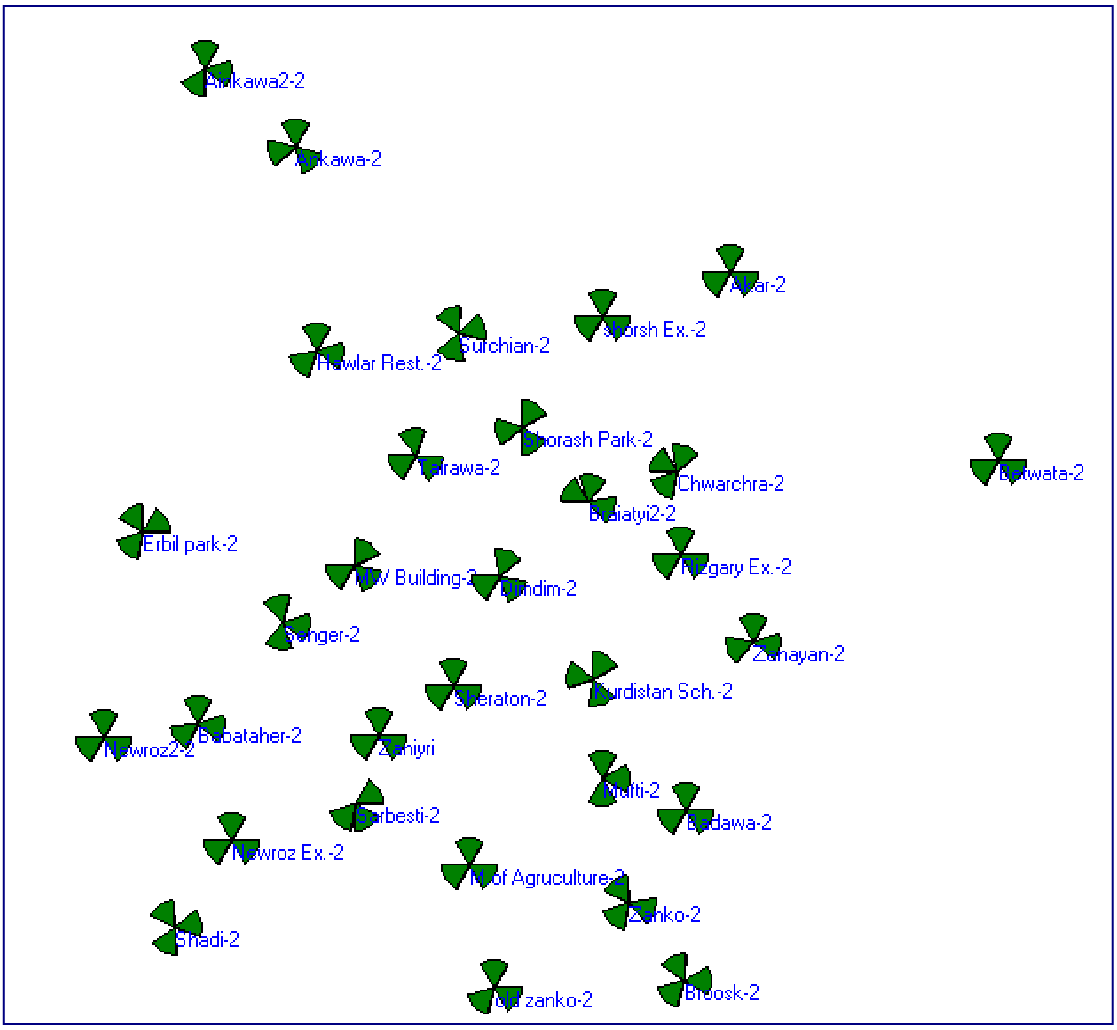


Figure 1-1: Distribution map of Huawei base stations in Erbil City

Figure 1-2: Drive test system configuration

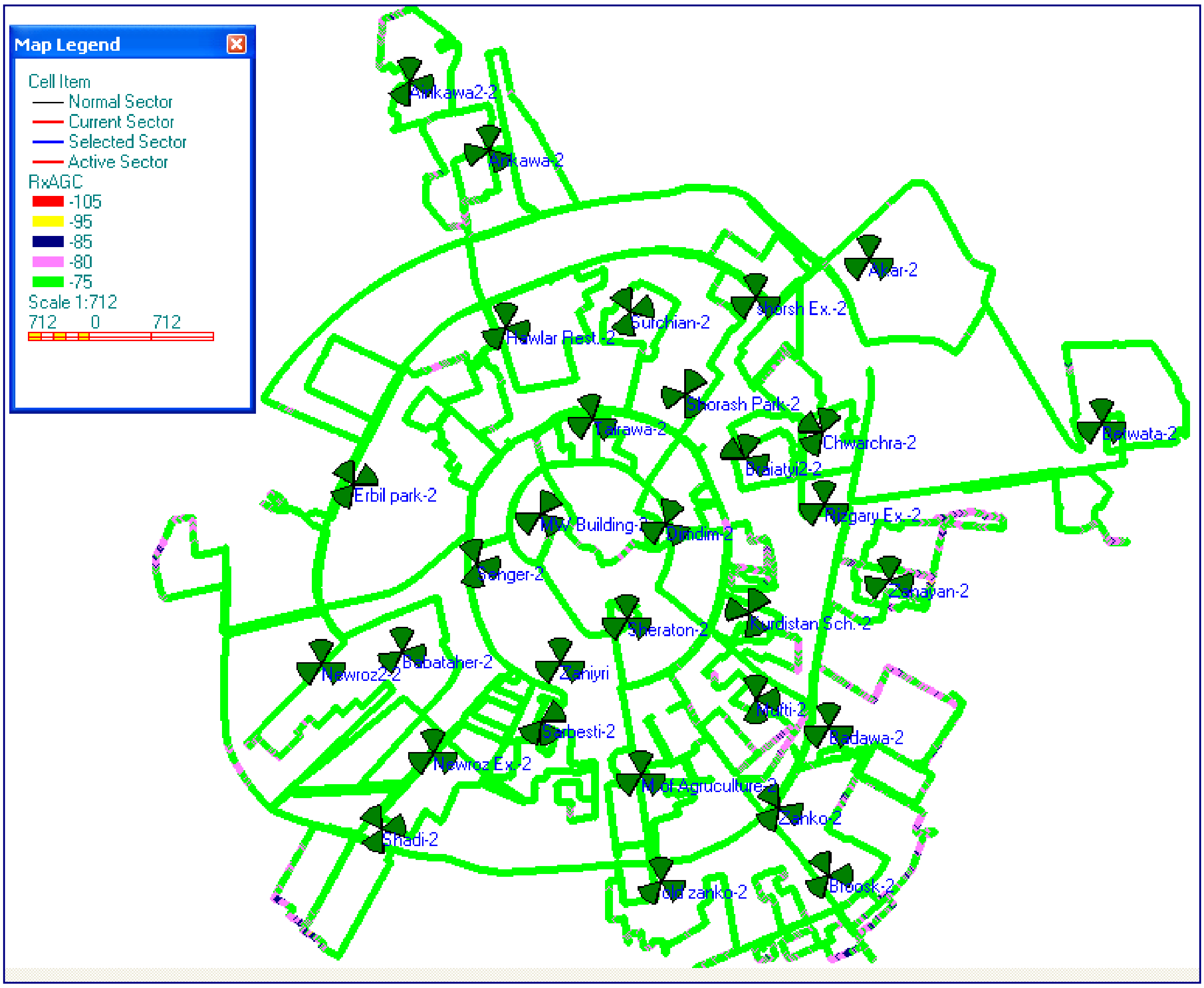
1 Drive Test Result and Analysis

1.1 *Analysis of Drive Test Result*

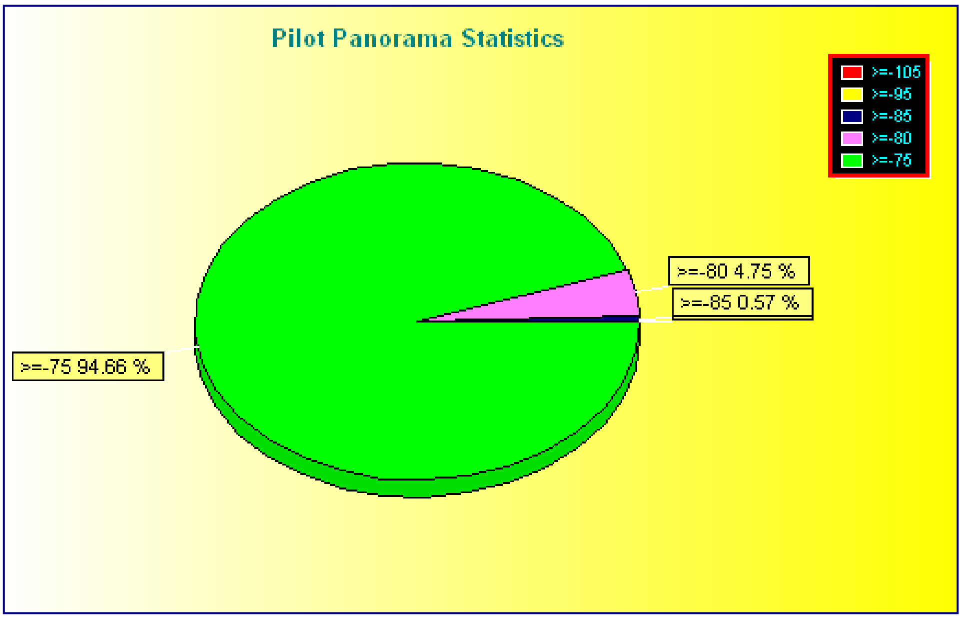
In order to know about the coverage of the network, we make a simple testing in outdoor.

1.1.1 Whole-network Rxdistribution and statistics

Whole-network Rxdistribution



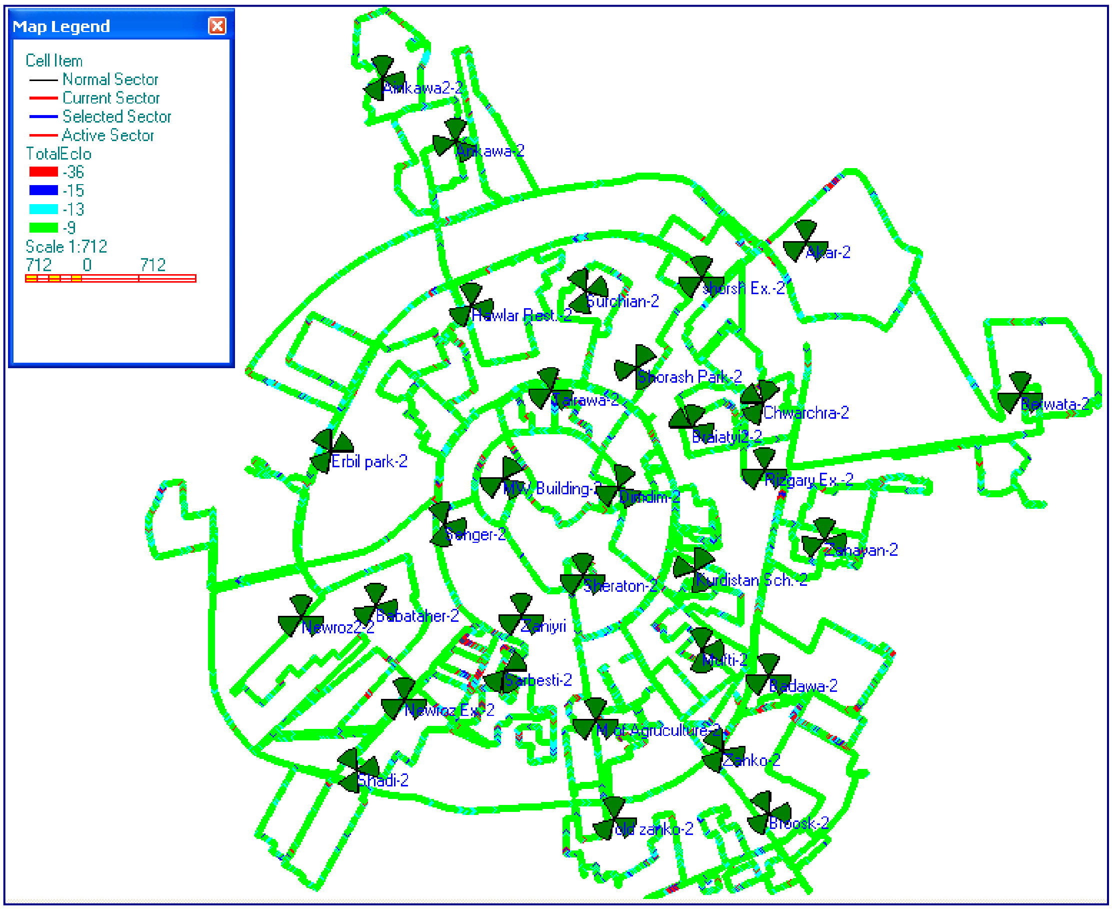
Whole-network Rxstatistics



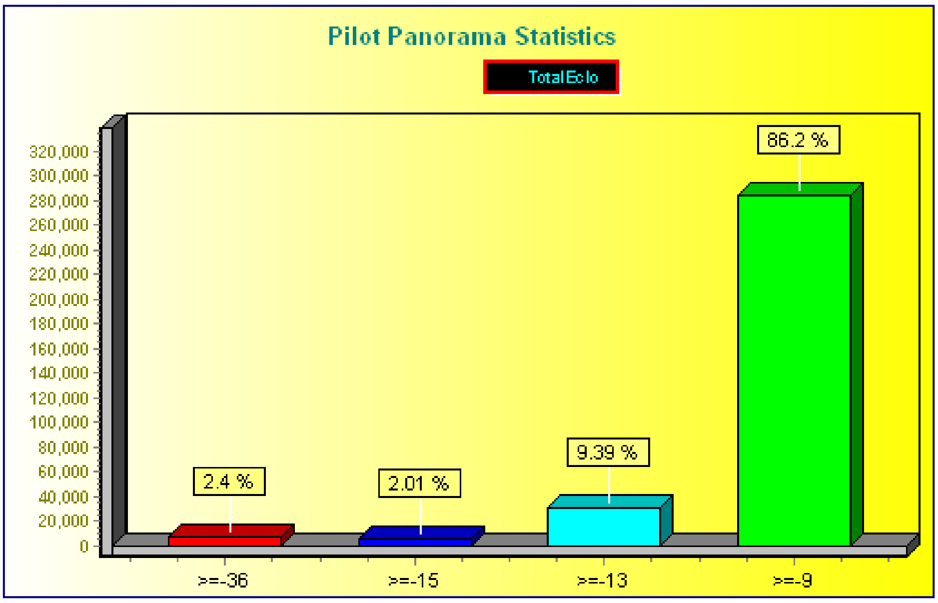
The areas that have very good Rx level (Rx >= -75 dBm) are 94.66% of the total tested areas. Totally there are 99.41% of the total tested area have good Rx level (Rx >= -80 dBm).This is good ratio for indoor coverage.

1.1.2 Whole-network Ec/Iodistribution and statistics

Whole-network Ec/Io distribution



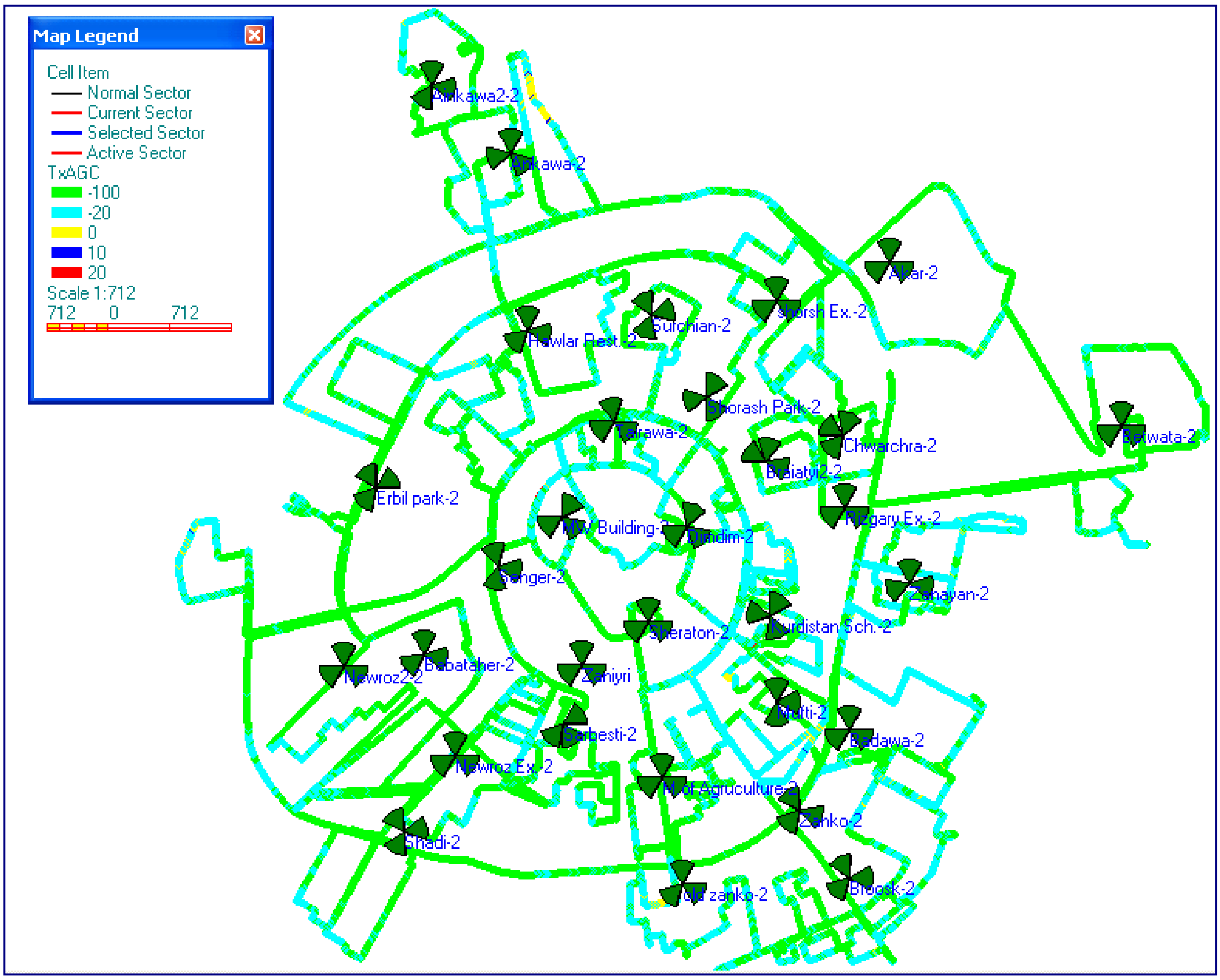
Whole-network Ec/Iostatistics



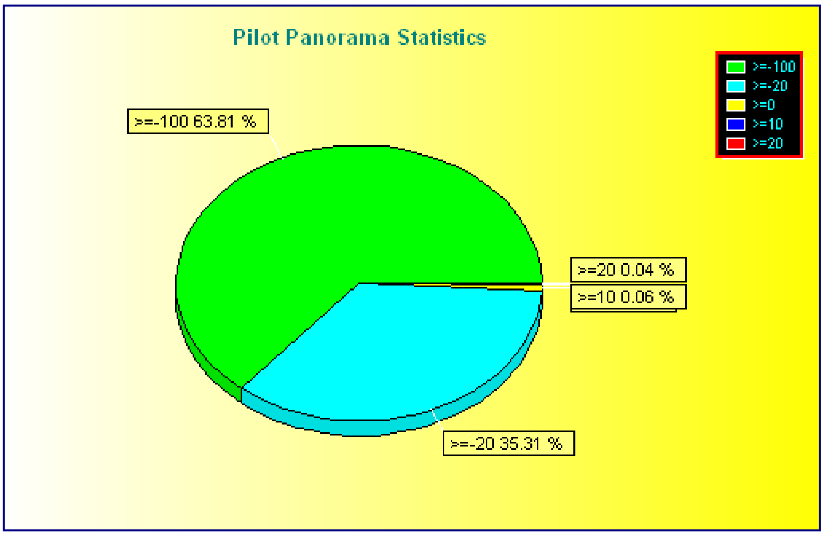
For the network, Ec/Io>= -9 is 86.2% and Ec/Io>= -13 is 9.39% of the tested areas. This also good ratio for normal communication.

1.1.3 Whole-network Tx distribution and statistics

Whole-network Tx distribution



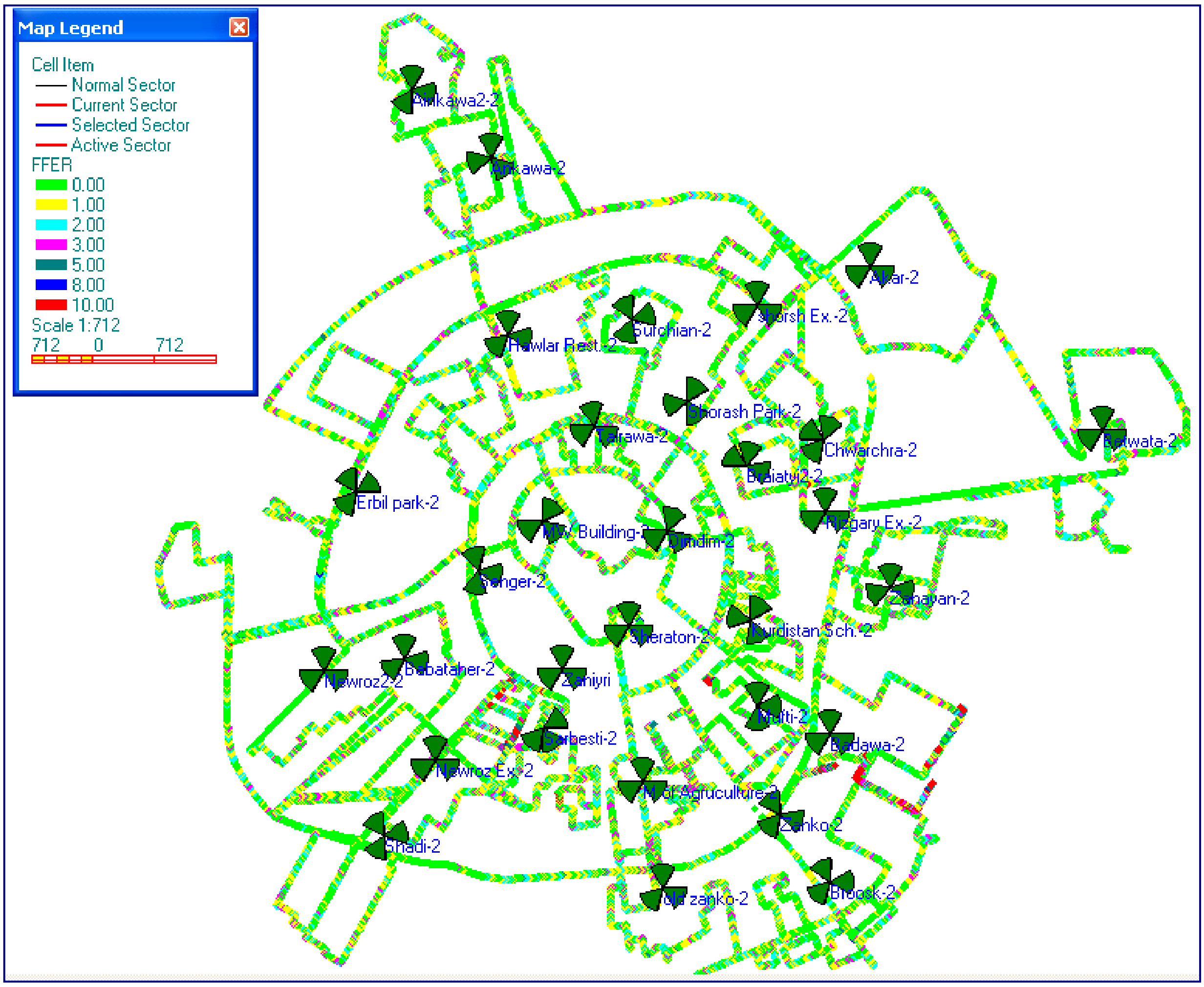
Whole-network Txstatistics



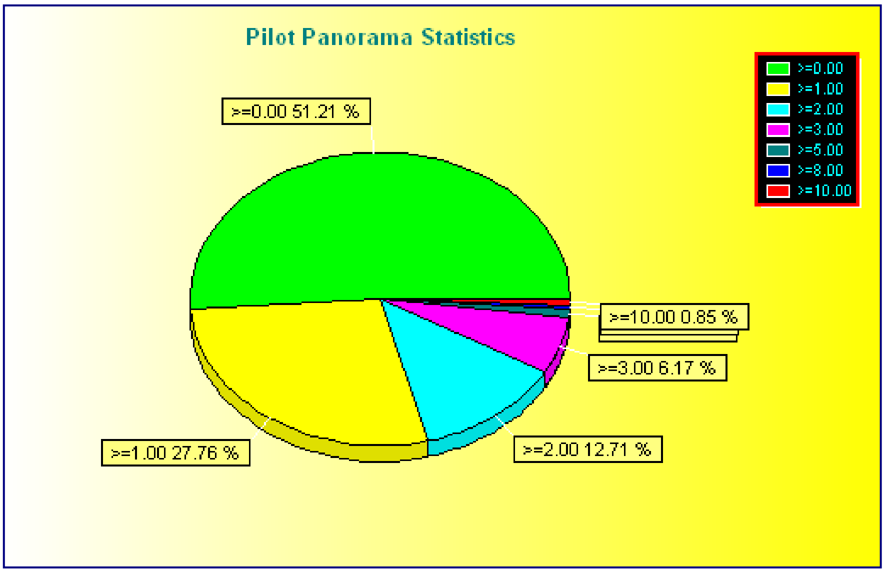
The Tx is good. That is the MS in 99.12% of the tested area transmit power less than -20dBm.

1.1.4 Whole-network FER distribution and statistics

Whole-network FER distribution



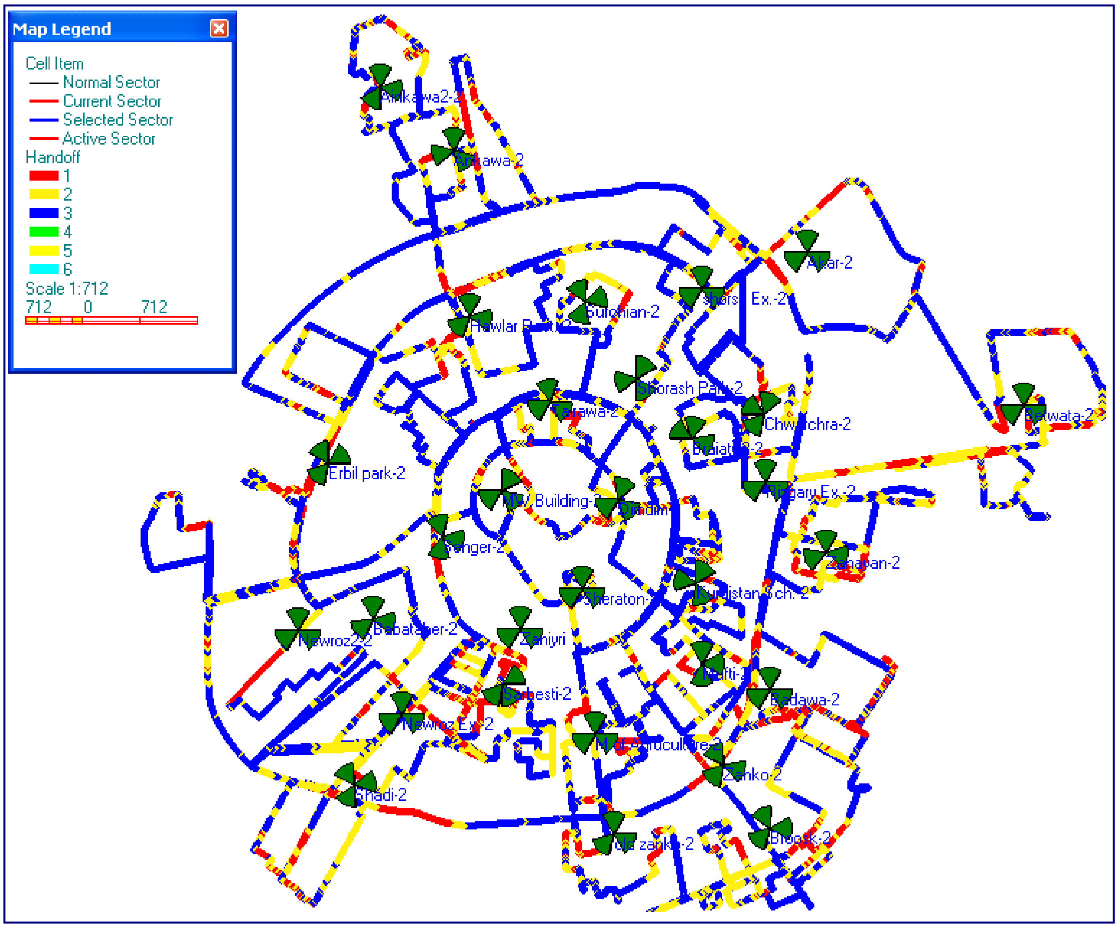
Whole-network FERstatistics



The areas that have FFER less than 3 are 91.68% of the total tested area. This is good ratio for voice service.

1.1.5 Whole-network Handoff distribution and statistics

Whole-network Handoff distribution



Whole-network Handoff statistics

Markov
MUXs
Handoff
HO Info
HO Timestamp
Call

Handoff Statistic

Total Occur 7139

Kind	Count	Percent%
Success	7104	99.51
Fail	35	0.49
S-Number	7139	100.00
S-Success	7104	99.51
S-Fail	35	0.49
H-Number	0	0.00
H-Success	0	0.00
H-Fail	0	0.00

Additions Scope

The HO success ratio is 99.51%. Good ratio for good service with minimum call drops.

2 Conclusion and suggestion

All the above results show us that the network status is good. That is the Rx, Tx, Ec/Io, FFER and Handoff, all these parameters with the good current level can support good indoor coverage, good voice quality with minimum call drops and easy network access. So we think the status of inside Erbil sites is good and no need for any adjustment.

Appendix D: Optimisations Tools User Guide

Two different measurements tools used to test the different technology Drive-testing (DT) remains an essential part of the network life cycle, as an effective means for continually optimising network performance to maintain customer satisfaction and reduce subscriber churn.

Due to variation of wireless propagation environment and demands of frequent expansion and upgrades as well as increase of number of subscribers, GSM/CDMA network optimization has become one of the daily and weekly important activates for all operators. Drive-test (DT) solutions are used for collecting measurement data over a CDMA air interface. The optimum solution combines network-independent RF (Radio Frequency) measurements using a digital receiver with traditional phone-based measurements.
A typical collection system includes a digital RF receiver, phone, PC, GPS receiver and antennas.
Both ZTE as a network equipment manufacturer and wireless service providers ITPC and any other providers need to perform drive-testing. Drive-testing allows them to perform this optimization on an on-going basis. Traditionally, GSM/CDMA drive- testing is performed using a phone connected to a portable computer. Cellular and PCS subscribers view the performance of their service on the basis of the network coverage or the call quality. The drive-test system makes these measurements, stores the data in the computer database, and stamps the data as a function of time and location. Frame Erasure Rate (FER) is a phone measurement that provides an indication of link quality.

Once the data has been collected over the desired RF coverage area, the data is out put to a post-processing software tool Zxpos CNAI. Engineers can use the post-processing and software analysis tools to identify the causes of potential RF coverage or interference problems and analyse how these problems can be solved. Once the problems identified, or reason for their causes, then steps are taken and performed to solve the problem.
ITPC deployed ZTE CDMA in Baghdad and Najaf so in this case it was decided to use ZTE wireless network optimization and test software for Baghdad as the main city and capital of Iraq with over 8 Millions residents also using Zxpos – CNTI (CDMA Network Testing) and Zxpos CNAI (CDMA Networks Analysis).

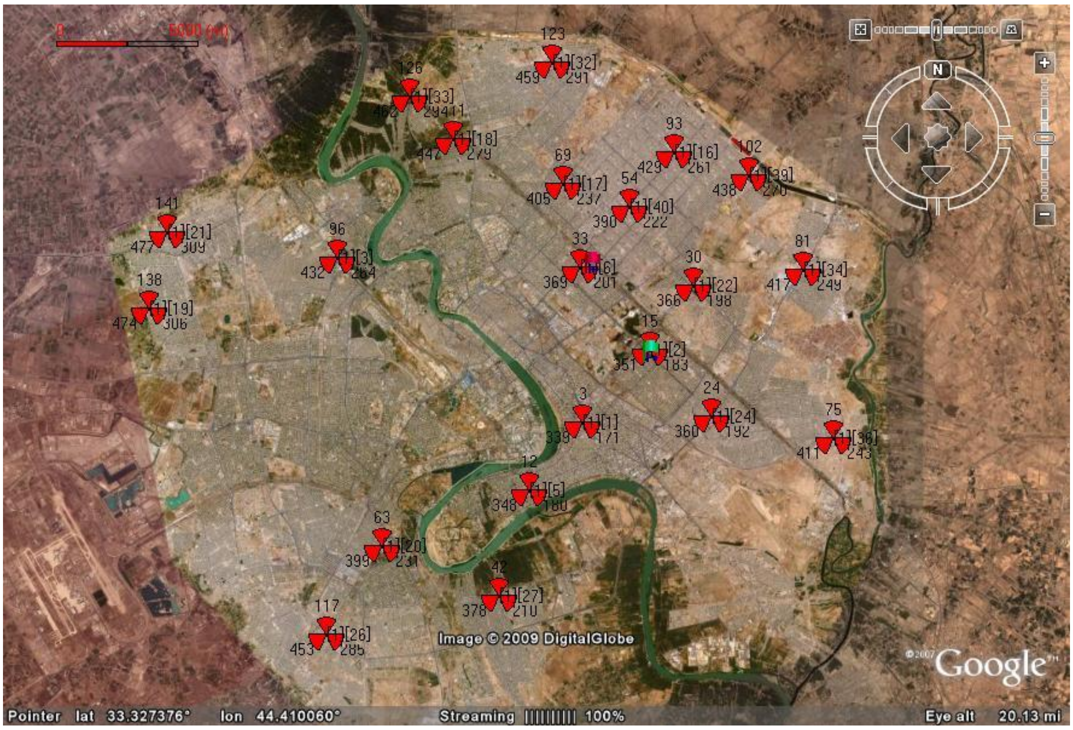


Figure 2: GPS of CDMA BTS

Devices Used for CDMA Measurements

1. Test terminal;
2. Direct test cable;
3. Laptop;
4. Power inverter, socket;
5. GPS and data cable;
6. ZXPOS CNT1: ZTE Drive Test Software for CDMA network;
7. ZXPOS CNA1: ZTE Analysis Software for CDMA network;
8. MapInfo digital maps;
9. Data card, cable.
10. Vehicle.

ZXPOS CNT1 is the professional foreground test software specially designed for communication networks. This software was used to collect and display various types of network data in real time, thus facilitating users to learn the network performance and diagnose existing problems in short time.

Communication Network Analyzer ZXPOS CNA1 has been adopted world wide by 140 operators in 53 countries and obtained wide acclaim because the advantages of its efficient and powerful functions. (ZTE Corporation, 2006)

ZXPOS (ZTE Network Planning & Optimization System) is the core tool kit of ZTE's communication network planning and optimization solution, which was designed and developed to simplify works in network planning and optimization and improve the RF engineers' working efficiency. It is composed of a comprehensive series of software tools about wireless network planning and optimization, namely: network plan and simulation system, network test system, and network performance optimization system, professional and enterprise applications, which supports whole network life cycle and supports 2G and 3G/B2G telecoms technologies such as GSM, IS-95 (Internet Standard-95) , CDMA2000 1X, CDMA2000, 1xEVDO, UMTS,TD-SCDMA(Time Division- Code Division Synchronous Multiple Access), WiMAX, LTE, etc.

ZXPOS CNA1 CDMA Network Optimization Analysis Software

The Software Analysis used has many Feature Functions as Follows:

• Function and Target: analyse the network intelligently based on the DT data and other assistant data for efficient optimization.

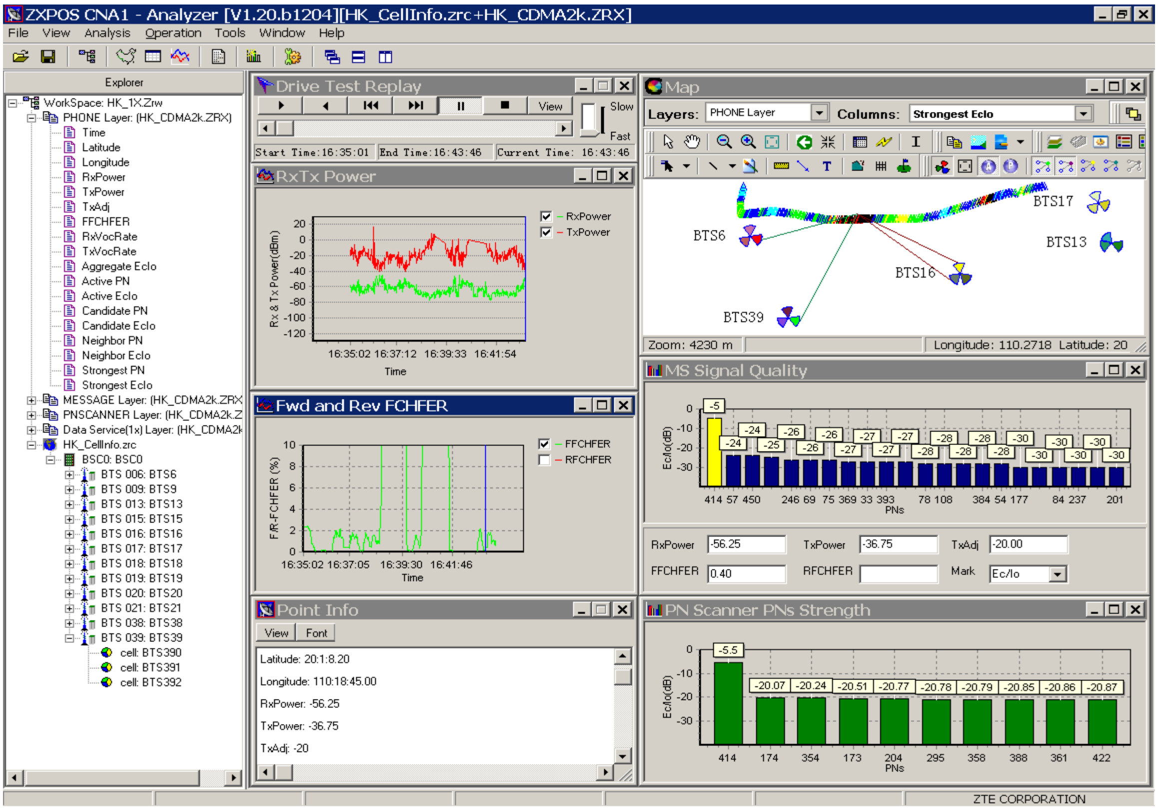


Figure 3: ZXPOS Software Analyses

- Support CDMA IS-95A/B, cdma2000-1x; 1x EV-DO, 1x EV-DV upgradeable;
  - Analysis based on DT data, OMC(Omnicom Group), simulation, site information, GIS information and etc.
  - Compatible with test data format, which is collected by Agilent DT equipment geographic display;
  - Support map, table and graph synchronous display and freely switch, multi-method analysis;
  - Professional Pilot diagnosis function, powerful Um message analysis including sync, paging, access and traffic channels;
  - Call Drop, Access failure, Handoff failure analysis

- Flexible Statistics and Report function, support statistics on certain geography area or certain period of time, and export Excel or Word style report;

- Provide Zoom, Offset, Bookmark, Select, Information display function, data map layers will have an offset automatically or by hand to avoid overlapped.

- Automatically associate Data map layer with Cell map layer by PN (Projection Neurons)

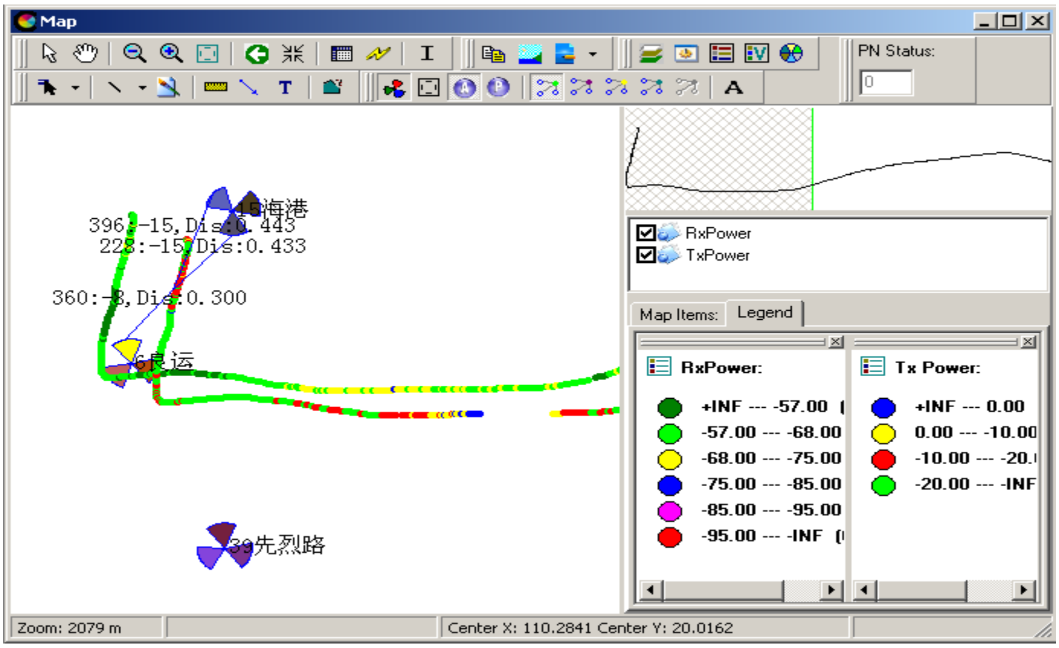


Figure 4:Data Map

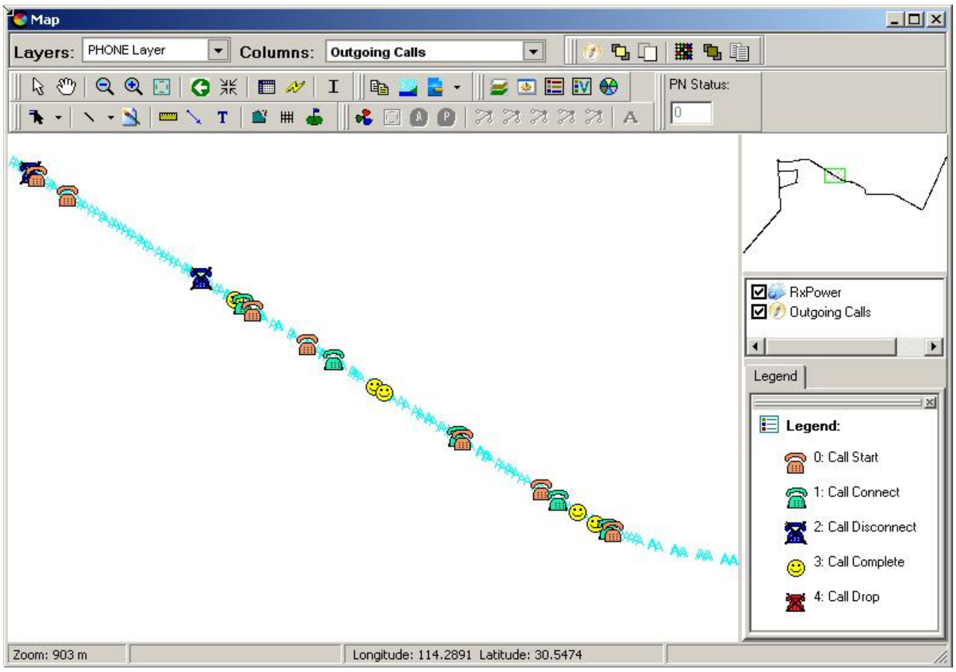


Figure 5: Outgoing Call Event geographic display

Air interface Setup Delay geographic display

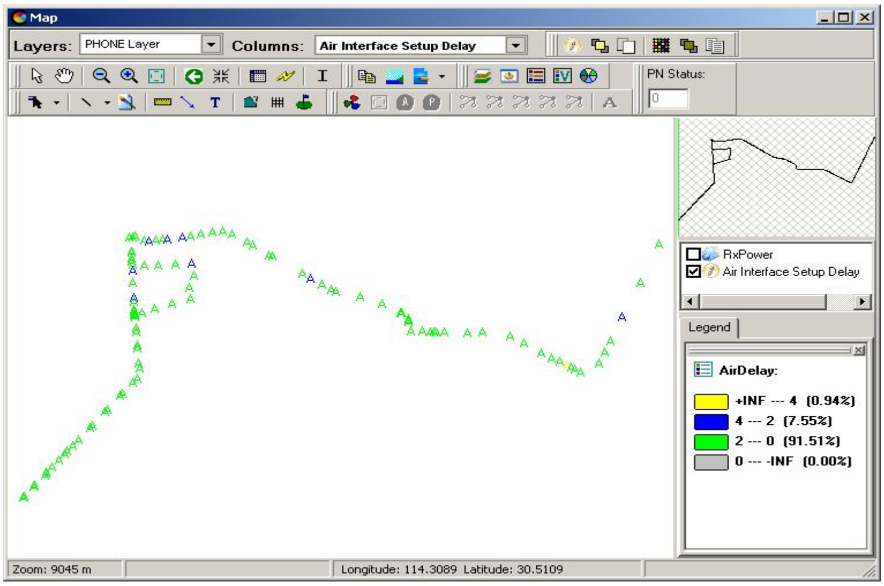


Figure 6: Air interface Setup Delay geographic display

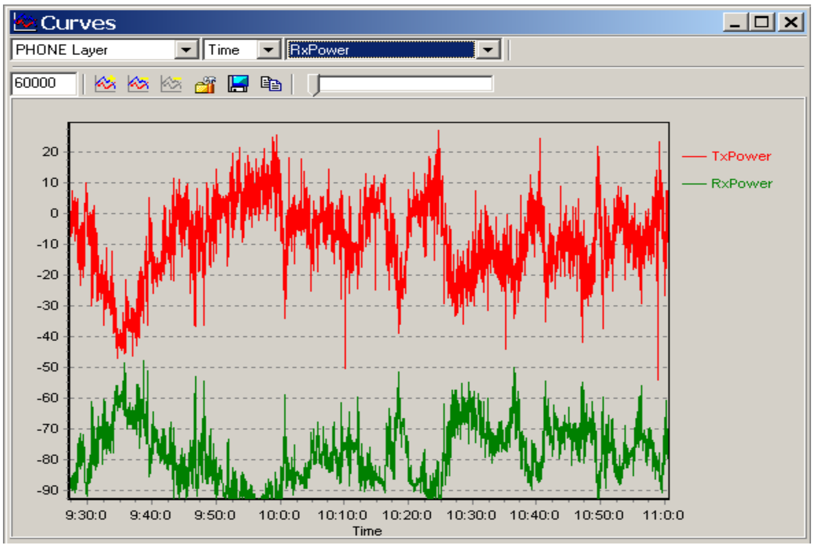


Figure7: Display the Parameter graphs in Histogram, Curve or Cake chart on two-dimension reference frame.

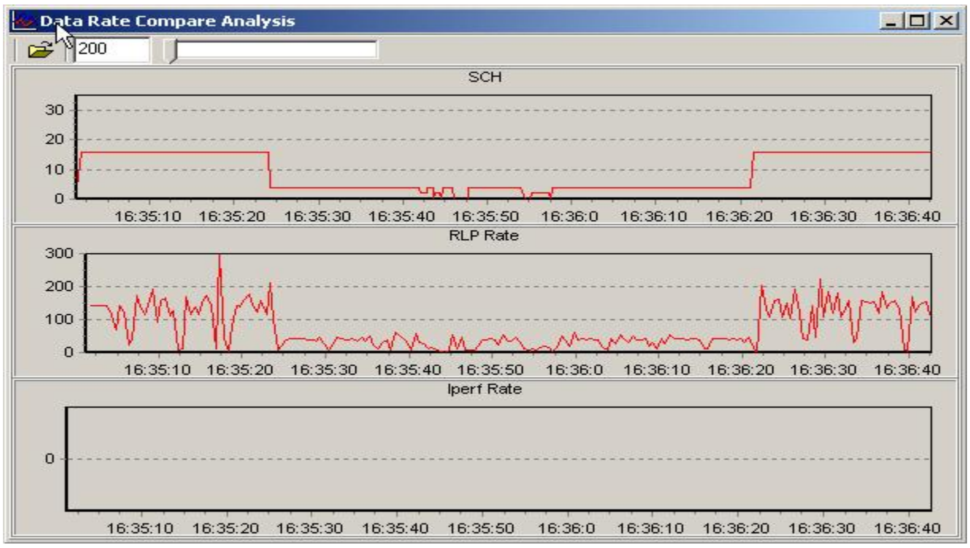
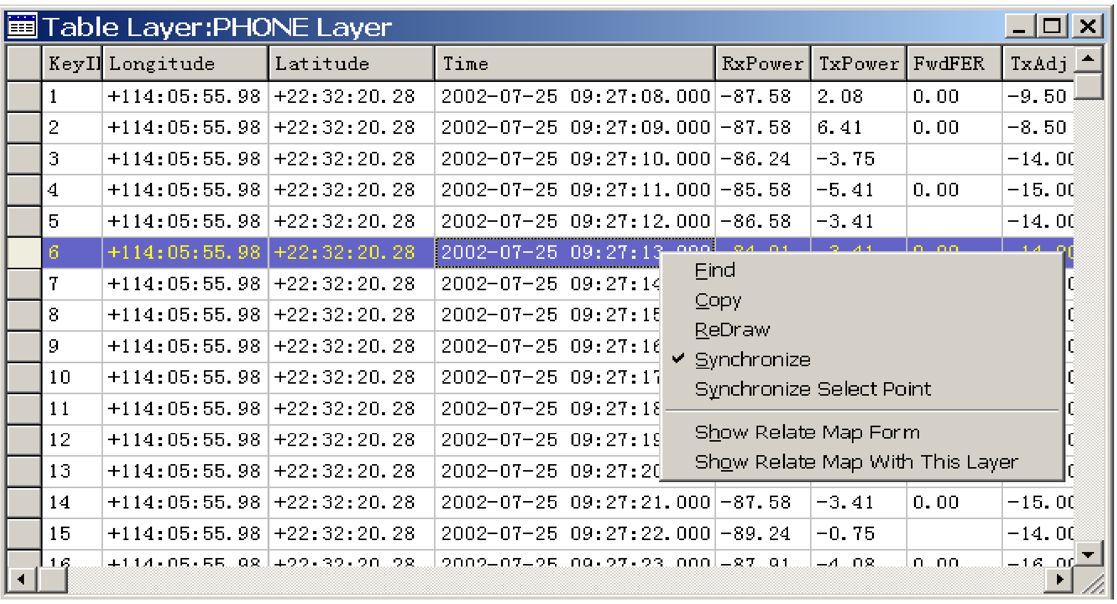


Figure 8: Data Rate Compare Analysis

•Display the parameters by its value,



KeyII	Longitude	Latitude	Time	RxPower	TxPower	FwdFER	TxAdj
1	+114:05:55.98	+22:32:20.28	2002-07-25 09:27:08.000	-87.58	2.08	0.00	-9.50
2	+114:05:55.98	+22:32:20.28	2002-07-25 09:27:09.000	-87.58	6.41	0.00	-8.50
3	+114:05:55.98	+22:32:20.28	2002-07-25 09:27:10.000	-86.24	-3.75		-14.0
4	+114:05:55.98	+22:32:20.28	2002-07-25 09:27:11.000	-85.58	-5.41	0.00	-15.0
5	+114:05:55.98	+22:32:20.28	2002-07-25 09:27:12.000	-86.58	-3.41		-14.0
6	+114:05:55.98	+22:32:20.28	2002-07-25 09:27:13				
7	+114:05:55.98	+22:32:20.28	2002-07-25 09:27:14				
8	+114:05:55.98	+22:32:20.28	2002-07-25 09:27:15				
9	+114:05:55.98	+22:32:20.28	2002-07-25 09:27:16				
10	+114:05:55.98	+22:32:20.28	2002-07-25 09:27:17				
11	+114:05:55.98	+22:32:20.28	2002-07-25 09:27:18				
12	+114:05:55.98	+22:32:20.28	2002-07-25 09:27:19				
13	+114:05:55.98	+22:32:20.28	2002-07-25 09:27:20				
14	+114:05:55.98	+22:32:20.28	2002-07-25 09:27:21.000	-87.58	-3.41	0.00	-15.0
15	+114:05:55.98	+22:32:20.28	2002-07-25 09:27:22.000	-89.24	-0.75		-14.0

Figure 9:Support Browse, Find and Analysis function.

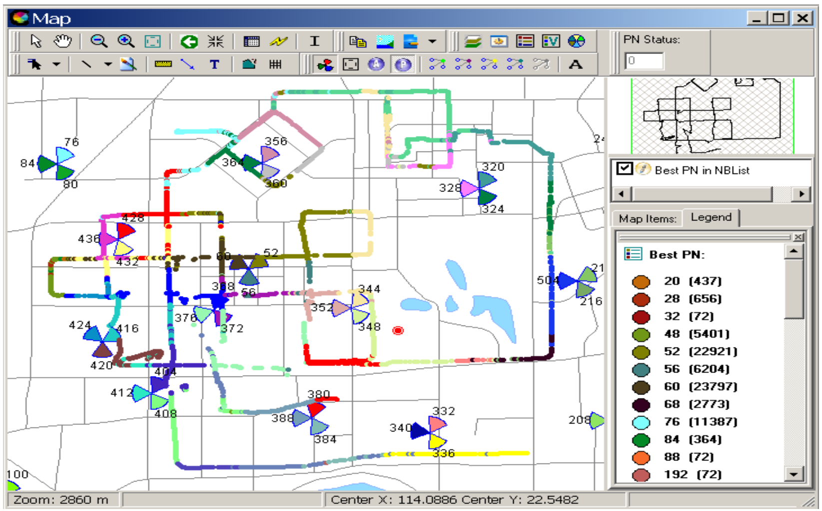


Figure 10: Pilot analysis – Strongest Ec/Io(Energy to Interference) analysis

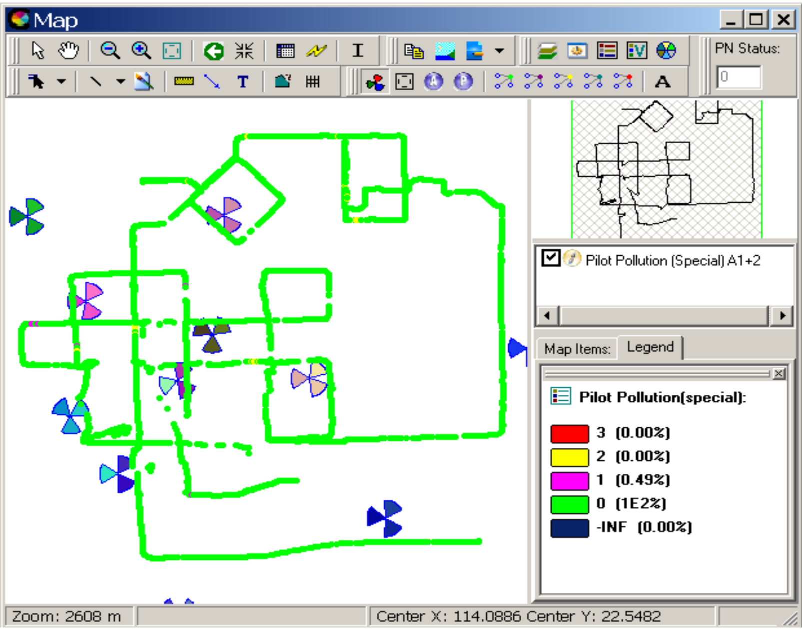


Figure 11: PN Pollution analysis

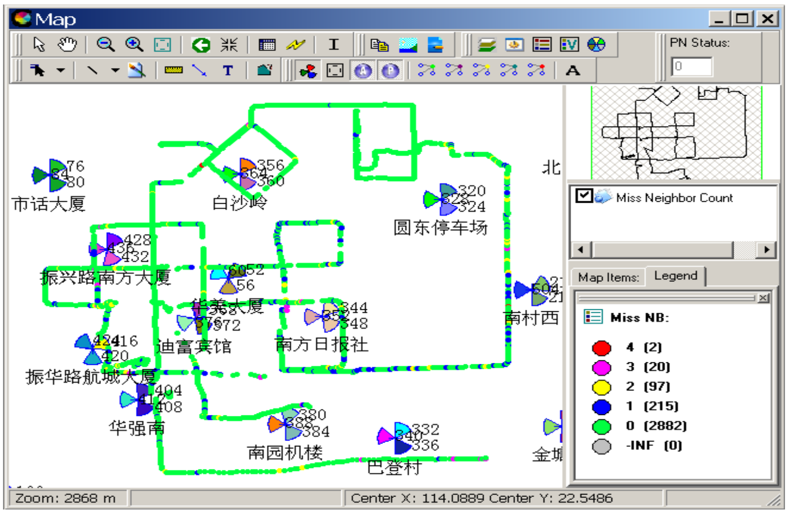


Figure 12: Miss Neighbour List analysis

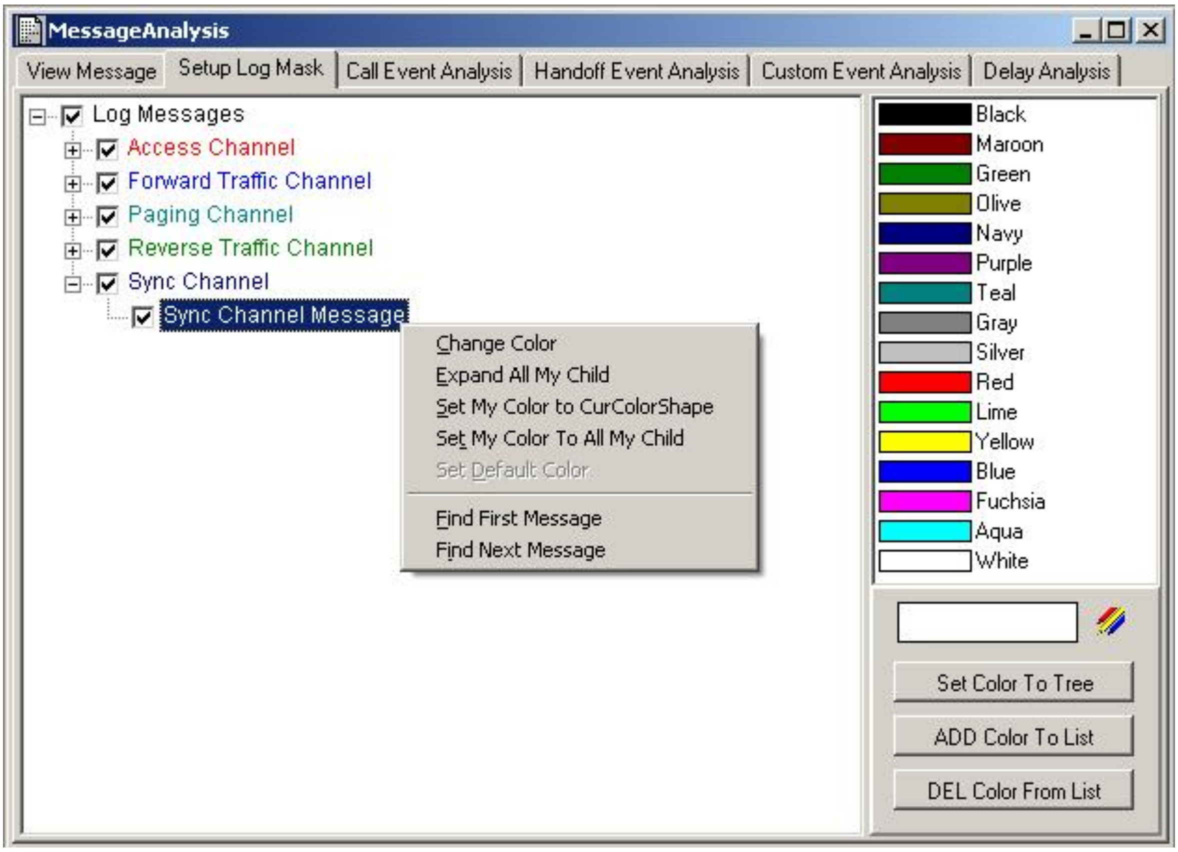


Figure 13: Message analysis – Display the message list in different colour and filter method, support Browse, Play, Find and Bookmark function

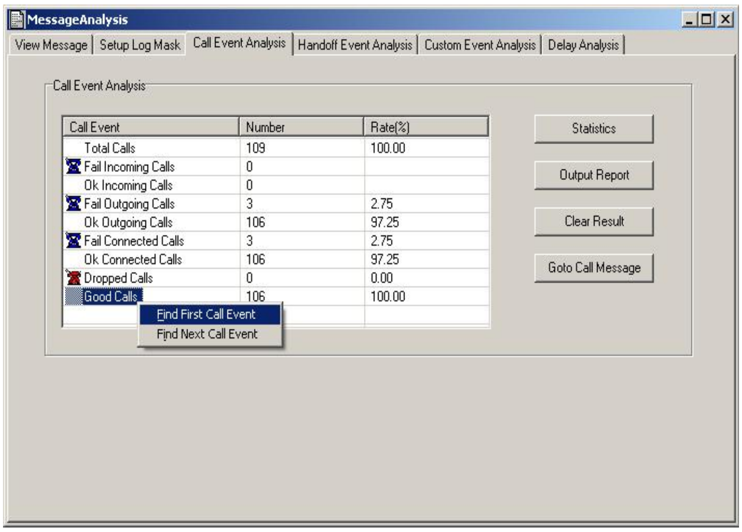


Figure 14: View message – Show detail decoded message in tree frame according to the Um Protocol

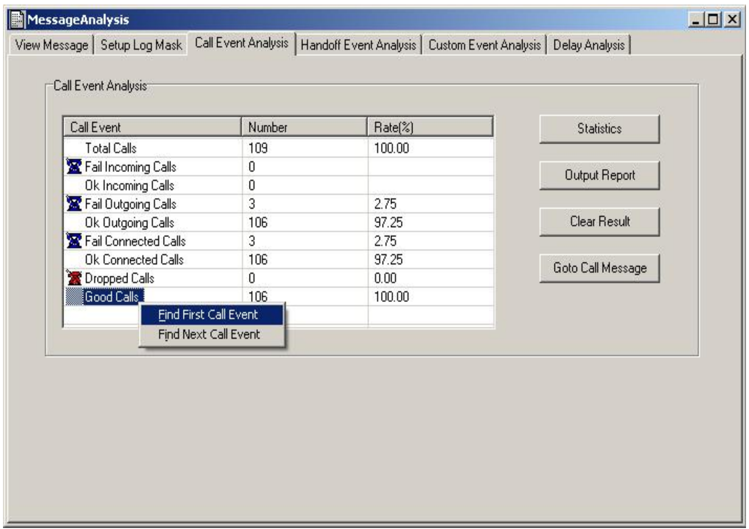


Figure 15: Call Event analysis

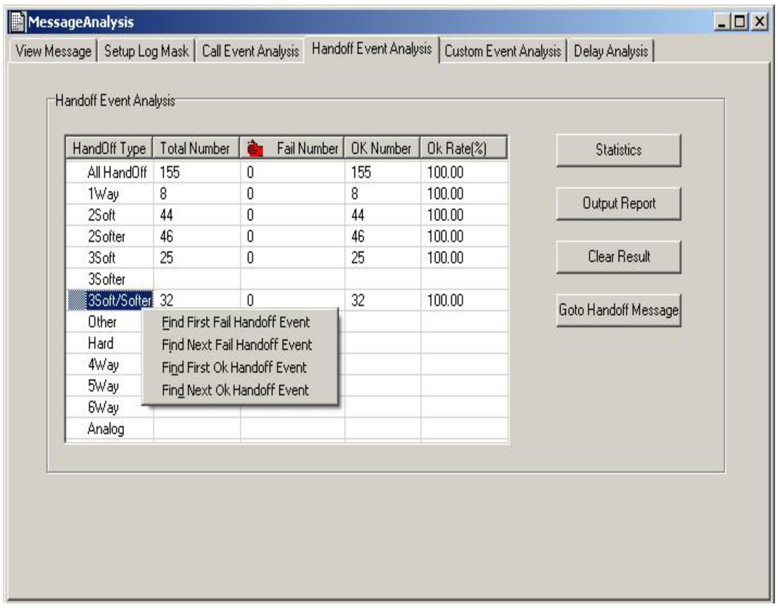


Figure 16: Handoff Event analysis

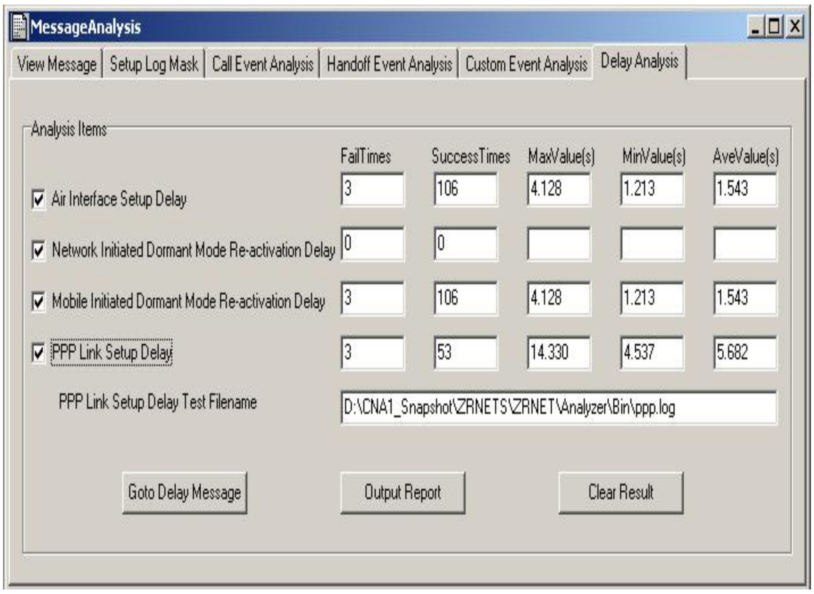


Figure 17: Delay analysis

Data Statistics

- Statistic the original data or Bin set data;

Three statistic style choices: Automatic, Custom, and Discrete

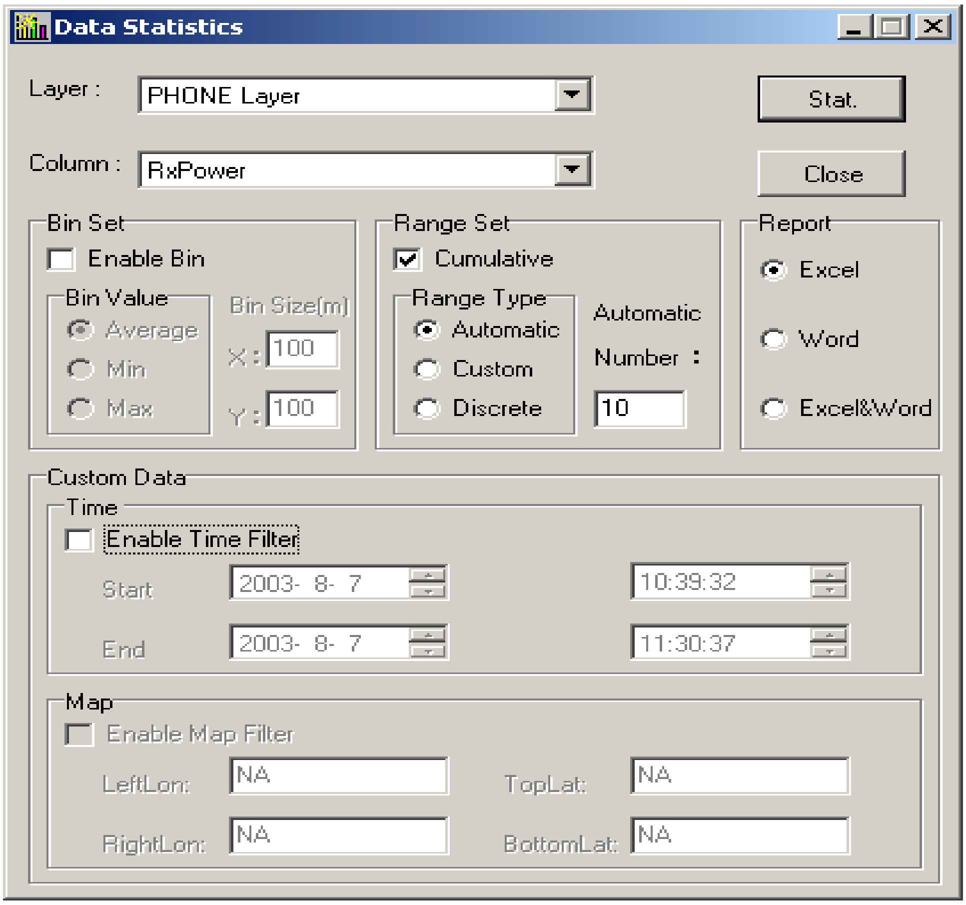
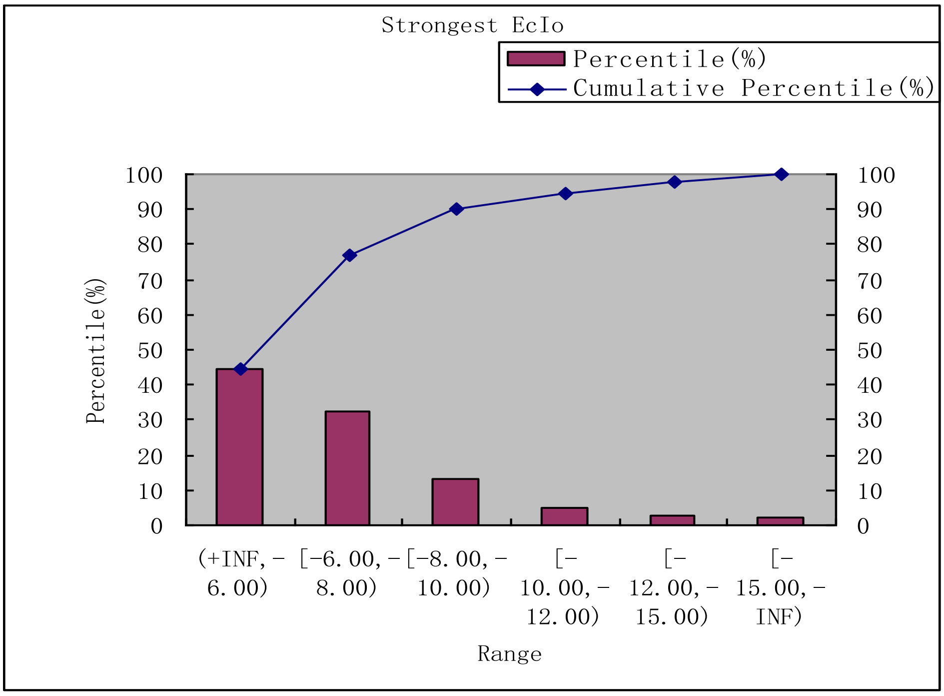
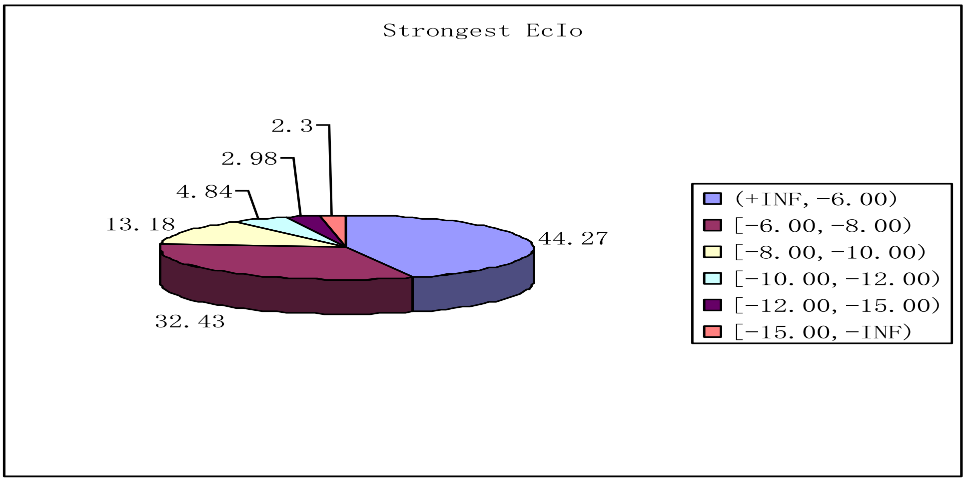


Figure 18:Data Set Statistics





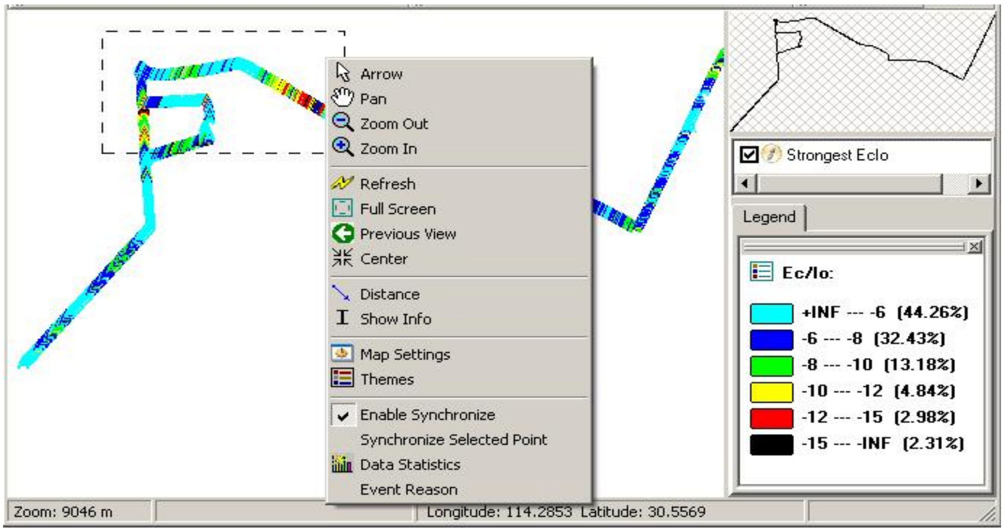


Figure 116: Certain area statistics

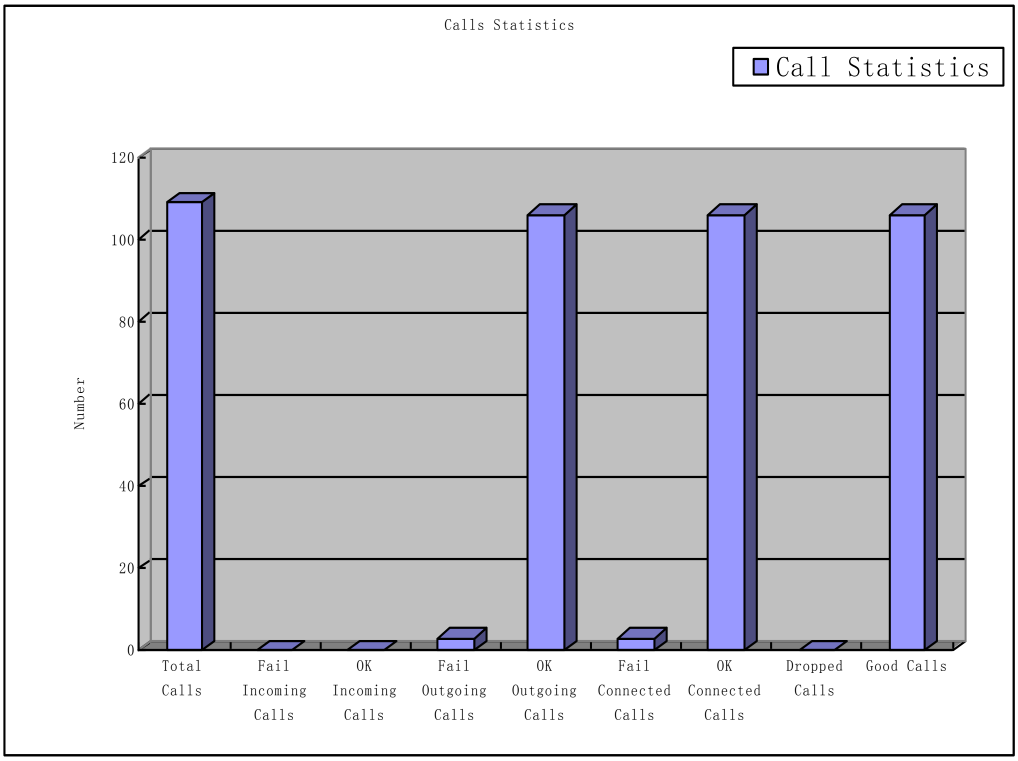


Figure 117: Custom Event analysis

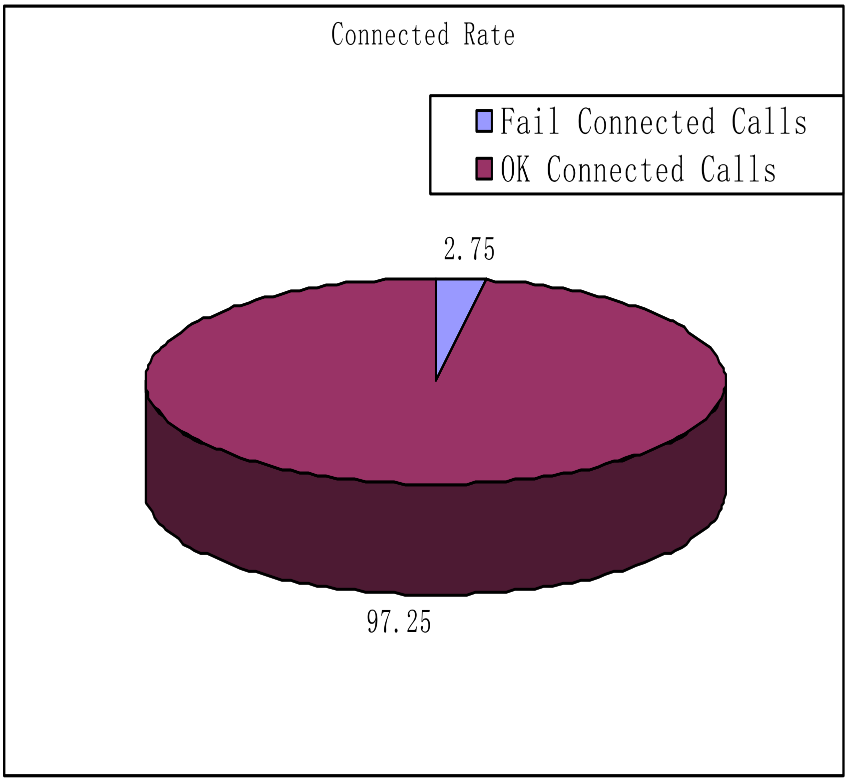


Figure 118: Connection Call Rate

ZXPOS CNT1 supports multiple phones to test at the same time, simultaneously with each terminal having its own performance parameter display window and control window. This supporting function expands the test on the network performance and provides wireless network engineers more flexible testing methods. This function is conducted in the following occasions: the test for both voice and data services simultaneously, the test for comparing networks with different modes, the test for mass traffic, the test for multiple carriers, and the performance test for comparing several terminals under the same network situation.(ZTE Corporation, 2006)

ZXPOS CNT1 has the function of testing diverse services, such as voice service, GoTa service, GPS One, PPP(Point to Point Protocol), FTP(File Transfer Protocol), HTTP (Hypertext Transfer Protocol) and PING. It also provides the sniffer function that can record PPP and TCP/IP data packets thus helping users to analyse faults more extensively. ZXPOS CNT1 also supports the customization of test plan, which can facilitate users to carry out tests on the scene. During the test process, the user can view various statistical data about tested service and detailed logs, which can help the user to quickly learn the network performance and locate network problems.

CTN1 have real time function also accurate geographic data display, network status and accurate location of the problem.(ZTE Corporation, 2006)

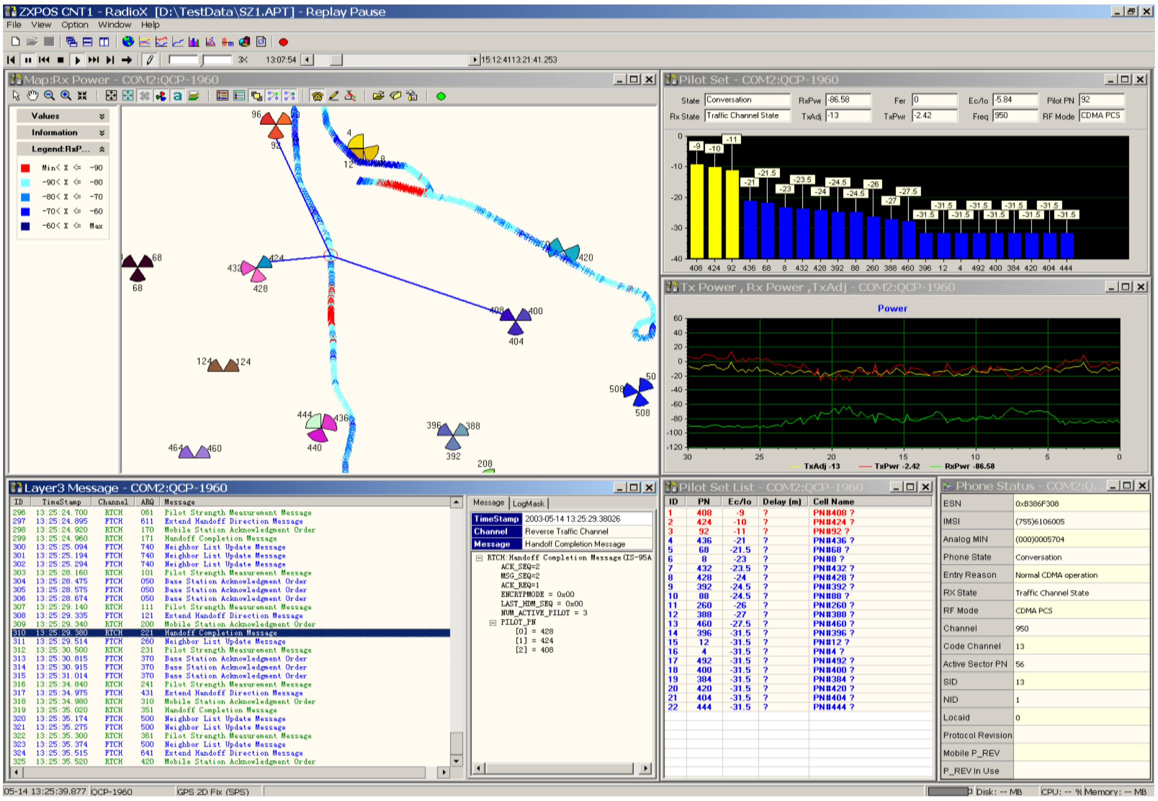


Figure 119: Real-time drawing Neighbour List connection.

Tools Key features:

- Support CDMA IS-95A/B, cdma2000-1X; 1x EV-DO, 1x EV-DV upgradable;
- Support all handsets measured complied with Qualcomm serial data control Standard, automatically device detect and connection recover, low battery and space alarms;
- Real-time geographic parameters display with different colours, adaptive to indoor test;
- Support flexible voice and data service test plan and auto-test, redial test; Analyse call failure reason and quickly locate the problem for voice service test;
- Quickly collect GPS information, handset diagnosis and data service layer information; Real-time display DT data in Text or Graph style;
- Powerful layer 3 message browse, real-time message decoding, and filtering and classified display;
- Scan all the 512 PN offsets, display fingers of each PN with delay, Ec, Ec/Io information etc.;
- Provide alarm function according to certain alarm definition by test project parameters;
- Support multi-handset measured complied with Qualcomm serial data control Standard
- Support all the GPS receiver measured complied with NMEA(National Marine Electrics Association) Standard by RS-232 (Recommended Standard-232)port
- Support disconnection automatically detects and recovers
- Support real-time multi-handset test.(locate problem cause by special type of handset)

Figure 120: Flexible test plans making

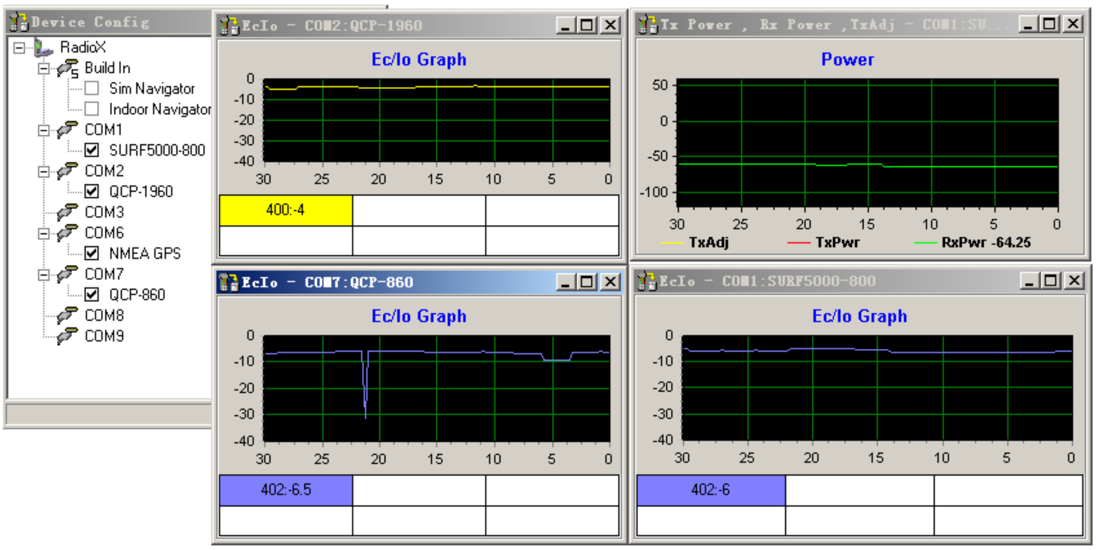
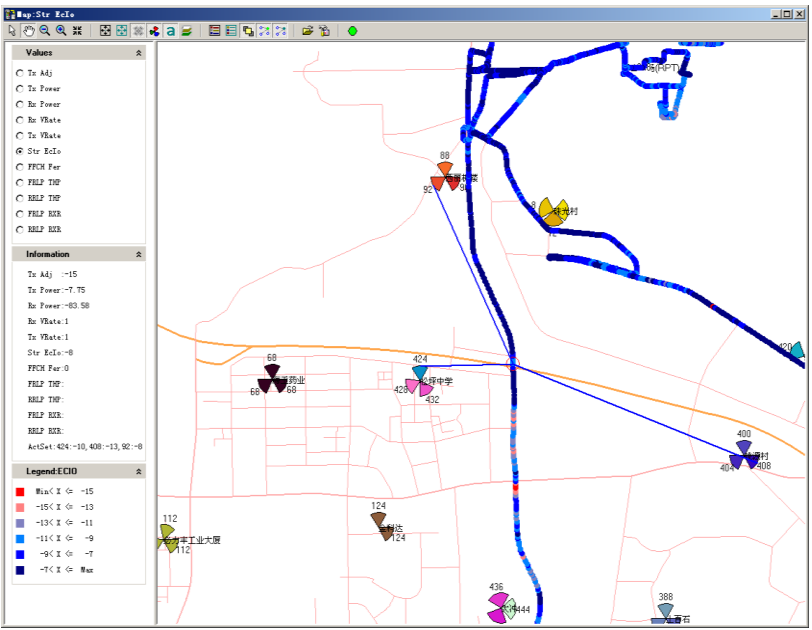


Figure 121: Real-time call process display, quickly locate the call failure reason



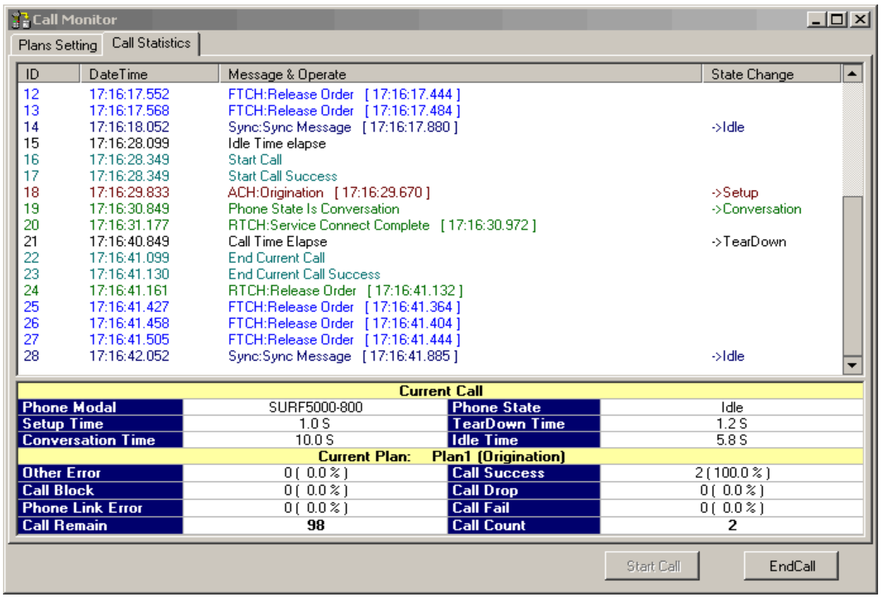


Figure 122: Real-time display the abnormal events during the test

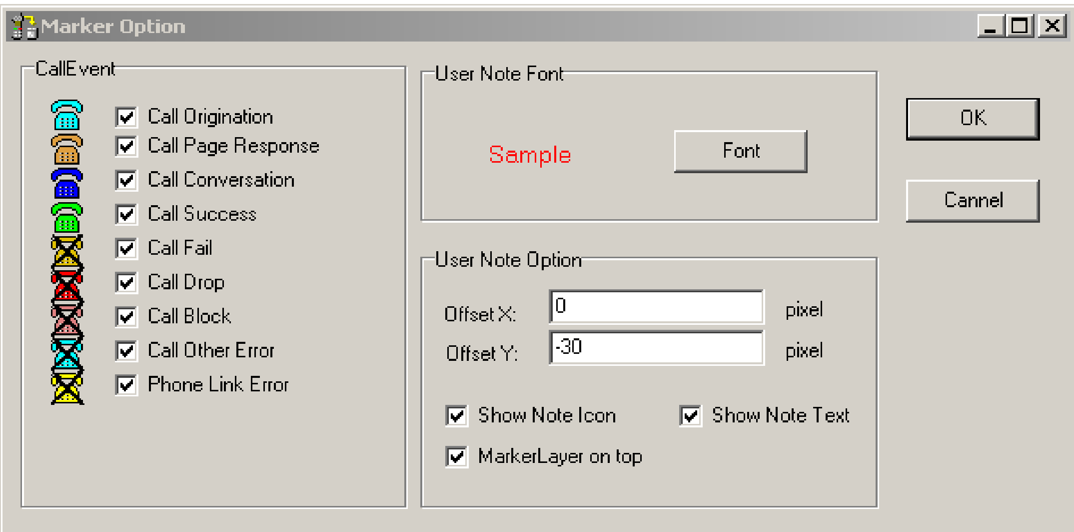


Figure 123: Collect and display function

Devices used for CDMA Frequency Scanning

11. TEK YBT250 Spectrum Analyzer
12. YagiAntenna type and Antenna Gain
13. GPS receiver
14. PCMCIA card (or Flash Memory/Serial Cable/Floppy Disk)
15. Laptop
16. Compass

The TEKYBT250 is a Tektronix Handheld, Multi-standard Base Station Transmitter Field and is used to measure power and verify the most important RF transmitter functions of GSM/GPRS, EDGE, W-CDMA/UMTS, CDMA One, CDMA2000 1x RTT, CDMA2000 1x EV-DO, TDMA and Analogue Base Stations interference analysis with high sensitivity. This includes AM (Amplitude Modulation) and FM(Frequency Modulation) demodulation and the identification of interference. It is based around the familiar Windows CE operating system. The Sequencer allows users to perform a customised selection of RF Power Carrier Frequency, Occupied Bandwidth, Code Domain Signal Quality, and Code Domain Power measurements. The YBT250 test module helps locate and Identify stray signals that cause dropped calls and poor quality service. To better see what signals may be polluting a Base Station receiver, the optional interference package allows measurements to –135 dBm. This sensitivity also makes the unit ideal for site surveys. The YBT250 test module also includes a spectrogram display, allowing the user to capture spectrum activity while displaying frequency, power level, and time information. (Tek, 2007)

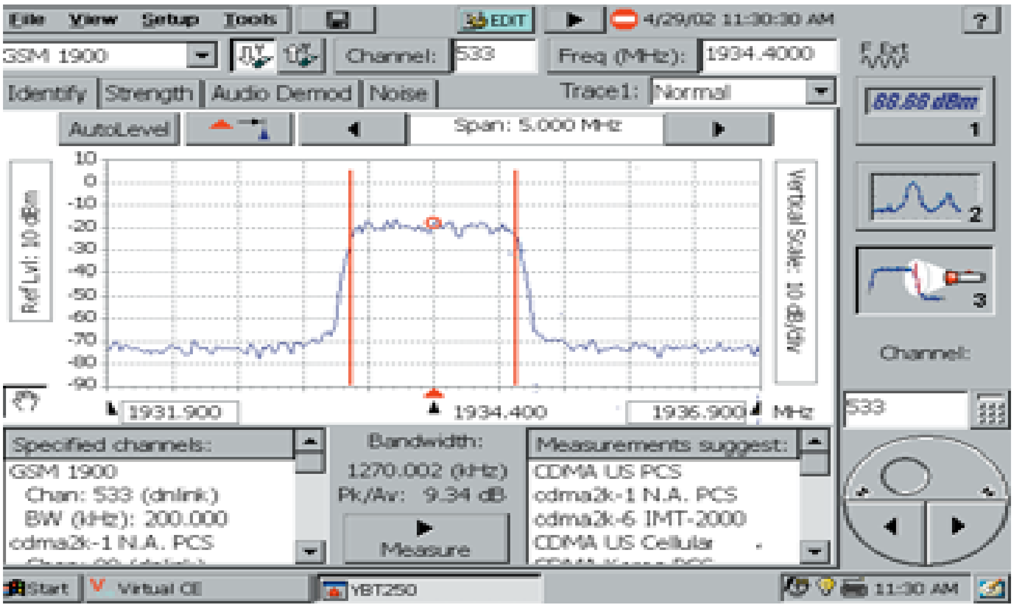


Figure 124: Rate of CDMA Frequency

TEMS Air Tool for Cellular Networks

TEMS (Telecommunications Expense Management Services) enables monitoring of voice and video telephony as well as a variety of data services over packet-switched and circuit-switched connections.

TEMS Investigation combines data collection, real time analysis and post- processing. i.e. Data Collection and Route Analysis.

Audio quality measurement (AQM) supported for both GSM/WCDMA and CDMA.

TEMS supports scanning of GSM radio frequency carriers with Sony Ericsson phones1 and PCTelSeeGull LX/EX scanners. GSM radio frequency carriers are sometimes referred to below as *channels* for simplicity. (ASCOM, 2009)

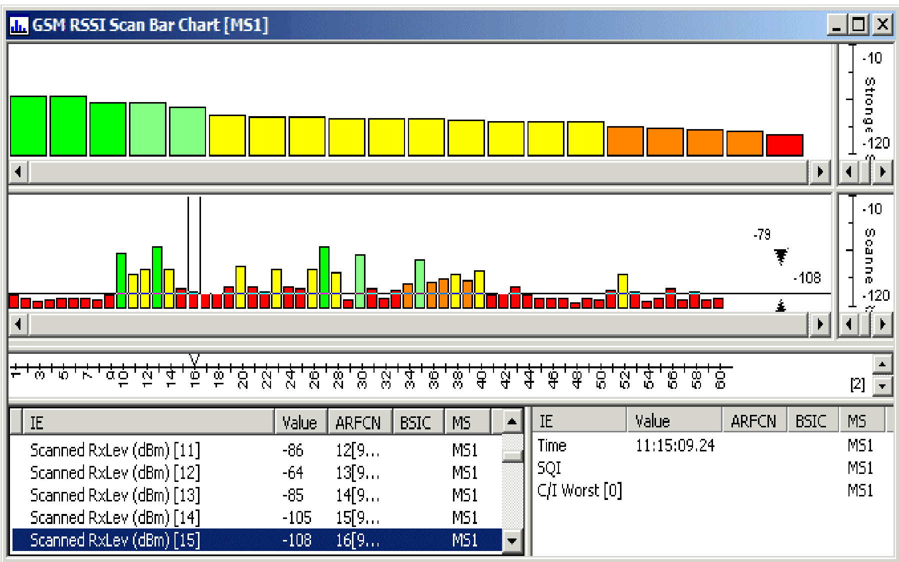


Figure 126: Signal Strength Measurements

The top chart by default shows the strongest scanned channels sorted by decreasing signal strength. The bottom chart by default shows all scanned channels in order of ascending ARFCN(Absolute Radio- Frequency Channel Number).

Using Command sequences to automate testing of packet-switched as well as circuit-switched services. To prerecord all of the commands to be given to devices during a drive test.

- Voice and video calls are supported. If you are using several phones, you can make them call each other automatically.

- Data service testing encompasses the following services and protocols: e- mail, FTP, HTTP, MMS, Ping, SMS, UDP(User Datagram Protocol), video streaming, and WAP(Wireless Application Protocol).

- The command sequence is also used to record data on which to base KPIs(Key Performance Indicator), indicating the performance of services.

TEMS Investigation Data Collection offers a set of KPIs (Key Performance Indicators) for measuring the user-perceived performance of a number of circuit-switched and packet-switched services. (ASCOM, 2009)

Measuring the to quality measure SQI (Speech Quality Index) for estimating the downlink speech quality in a GSM or CDMA cellular network as perceived by a human listener. Computing SQI for GSM and WCDMA requires data collected with Sony Ericsson phones. SQI for CDMA can be based on data from any CDMA phone that is connectable in TEMS Investigation. (Ericsson technical Paper, 2008)

PESQ, short for Perceptual Evaluation of Speech Quality, is the industry standard for voice quality measurement. The PESQ algorithm measures end- to-end speech quality by comparing one party’s undistorted input signal (serving as reference) with the degraded version of the same signal received by the other party. The severity of the degradation as perceived by human listeners is assessed using highly refined models of the human ear and the brain’s processing of auditory input. (Ericsson technical Paper, 2008)
The PESQ algorithm is defined by the ITU standard P.862.

The computation of AQM (Audio Quality Measurements) scores is done in dedicated hardware units called AQM modules: one connected to the phone and to the PC, handling the downlink; and one housed in the Call Generator, taking care of the uplink. These modules contain DSP(Digital Signal Processing) hardware. The downlink AQM module can optionally be mounted along with the phone in an equipment case. (Ericsson technical Paper, 2008)

The measurement procedure can be summarised as follows:

- The speech segments to be used as references are loaded into the AQM modules and into the test phone.
- The phone calls the Call Generator and plays the reference sentences. The Call Generator responds by playing the same reference sentences.
- The received (degraded) signals at either end are forwarded to the respective AQM modules, where the signals are compared with the originals, yielding uplink and downlink PESQ scores. The AQM modules also record a number of further audio quality measurements such as echo delay, echo attenuation, and volume.
- The downlink AQM data is written to regular TEMS Investigation log files.

The uplink AQM data is stored in XML files.

The carrier-over-interference ratio is the ratio between the signal strength of the current serving cell and the signal strength of undesired (interfering) signal components. The C/I (Co-Channel Interference) measurement function built into TEMS Investigation enables the identification of frequencies that are exposed to particularly high levels of interference, something that comes in useful in the verification and optimization of frequency plans.
To obtain a correct C/I estimate, one must take into account the possible use of power control and/or discontinuous transmission (DTX). In the past, rough C/I measurements have carried out occasionally by comparing the BCCH(Broadcast Control Channel) signal power of the serving cell with that of neighbouring cells using the same traffic channels (but different BCCHs). Since such a scheme fails to allow for power control and DTX on the TCHs, it may produce misleading results. (Goksel, 2003)

In dedicated mode, average C/I is presented approximately twice a second, which is equal to the ordinary measurement interval. If frequency hopping is employed, the average C/I for each frequency is presented.

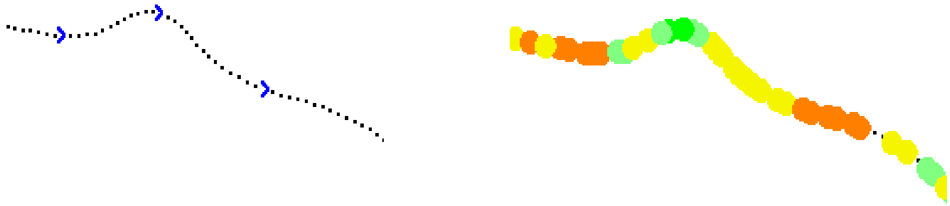
The measurement range extends from 0 dB to 35 dB. A C/I below 0 dB can be regarded as highly unlikely; in addition, if the number of hopping frequencies is low, C/I values below this limit would normally result in a dropped call. Beyond the upper limit, the performance is not further improved. Hence, the limitation of the measurement range is not a restriction.
If downlink DTX is used, the number of bursts transmitted from the base station to the phone may be lower than the maximum, depending on the speech activity level on the transmitting side. TEMS Investigation makes measurements only on the bursts actually sent from the base station and disregards bursts not transmitted. (Goksel, 2003)

There are many possible causes of poor C/I values. Two common ones are co-channel and adjacent channel interference. In certain circumstances, however, the main problem is not interference from other callers, but the fact that the signal is overwhelmed by assorted random disturbances – i.e. what is usually called “noise”. This means thermal noise generated within the circuits of the phone as well as external background noise from a plethora of sources, including other man-made signals so faint that they merely add up to a quasi-random disturbance.

Using Route Analysis is a post-processing tool for data collected with TEMS Investigation Data Collection.

Most of the functionality of Route Analysis is designed for on-screen analysis of one or several logs files. The Data Selector and the Map are specifically intended for analysing multiple log files. The remaining presentation windows, on the other hand, always present one log file at a time.

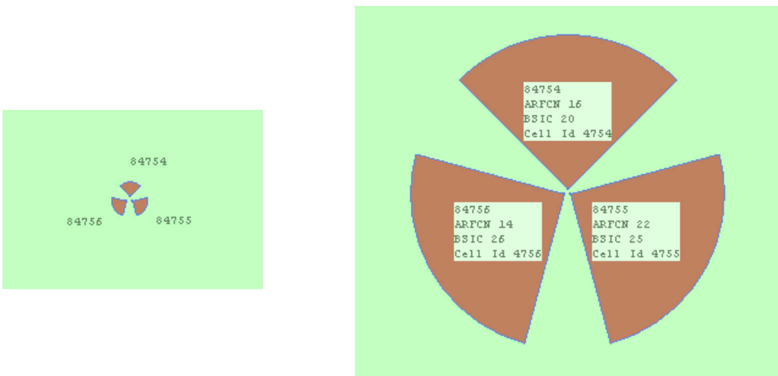
The route is traced by a black dotted line (“Trail” on the Legend tab), labelled at regular intervals with blue arrows that indicate the direction of travel. Information element route markers, where drawn, will be plotted on top of the trail and hide it.



5'#-A0. AN　　　　5'#-A#. / ('0H%&(D#'P&'2

Figure 129: Trail Routes

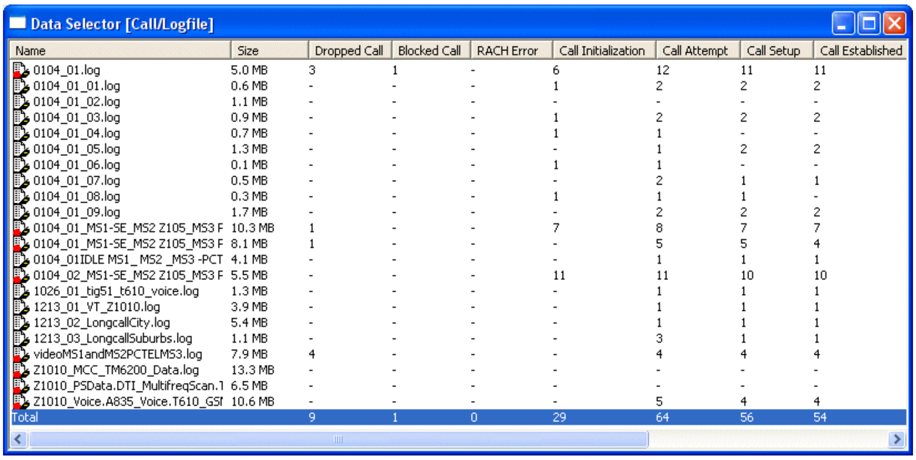
GSM cells are always labelled with their names, regardless of zoom. If you zoom in enough on a cell, the text label becomes more detailed



V/ / F) @%4+　　　　A6 *) W=

Figure 130: TEMS Zoom

The strength of the Route Analysis application lies in its ability to analyse large numbers of log files, sifting through large volumes of data, and quickly pointing out where trouble lies. Moreover, data can be categorised not only by log file but also *by* serving cell, enabling rapid identification of cells plagued by frequent problems. (Goksel, 2003)



Data Selector [Call/Logfile]

Name	Size	Dropped Call	Blocked Call	RACH Error	Call Initialization	Call Attempt	Call Setup	Call Established
0104_01.log	5.0 MB	3	1	-	6	12	11	11
0104_01_01.log	0.6 MB	-	-	-	1	2	2	2
0104_01_02.log	1.1 MB	-	-	-	-	-	-	-
0104_01_03.log	0.9 MB	-	-	-	1	2	2	2
0104_01_04.log	0.7 MB	-	-	-	1	1	-	-
0104_01_05.log	1.3 MB	-	-	-	-	1	2	2
0104_01_06.log	0.1 MB	-	-	-	1	1	-	-
0104_01_07.log	0.5 MB	-	-	-	-	2	1	1
0104_01_08.log	0.3 MB	-	-	-	1	1	1	-
0104_01_09.log	1.7 MB	-	-	-	-	2	2	2
0104_01_MS1-SE_MS2 Z105_MS3 F	10.3 MB	1	-	-	7	8	7	7
0104_01_MS1-SE_MS2 Z105_MS3 F	8.1 MB	1	-	-	-	5	5	4
0104_01IDLE MS1_ MS2 _MS3 -PCT	4.1 MB	-	-	-	-	1	1	1
0104_02_MS1-SE_MS2 Z105_MS3 F	5.5 MB	-	-	-	11	11	10	10
1026_01_tig51_t610_voice.log	1.3 MB	-	-	-	-	1	1	1
1213_01_VT_Z1010.log	3.9 MB	-	-	-	-	1	1	1
1213_02_LongcallCity.log	5.4 MB	-	-	-	-	1	1	1
1213_03_LongcallSuburbs.log	1.1 MB	-	-	-	-	3	1	1
videoMS1andMS2PCTELMS3.log	7.9 MB	4	-	-	-	4	4	4
Z1010_MCC_TM6200_Data.log	13.3 MB	-	-	-	-	-	-	-
Z1010_PSData.DTI_MultifreqScan.1	6.5 MB	-	-	-	-	-	-	-
Z1010_Voice.A835_Voice.T610_GSI	10.6 MB	-	-	-	-	5	4	4
Total		9	1	0	29	64	56	54

Figure 131: Log files.

The Data Selector is now loaded with columns counting the occurrences of call events. By default the counting is done by log file. We sort on the Dropped Call column to rank log files according to the number of dropped calls.

We are now interested in studying this cell close up, so we right-click it and choose View in Map. All routes involving interaction with the cell in question are then drawn on the map. In the screenshot below, we can immediately identify one of the dropped calls (indicated by the arrow).

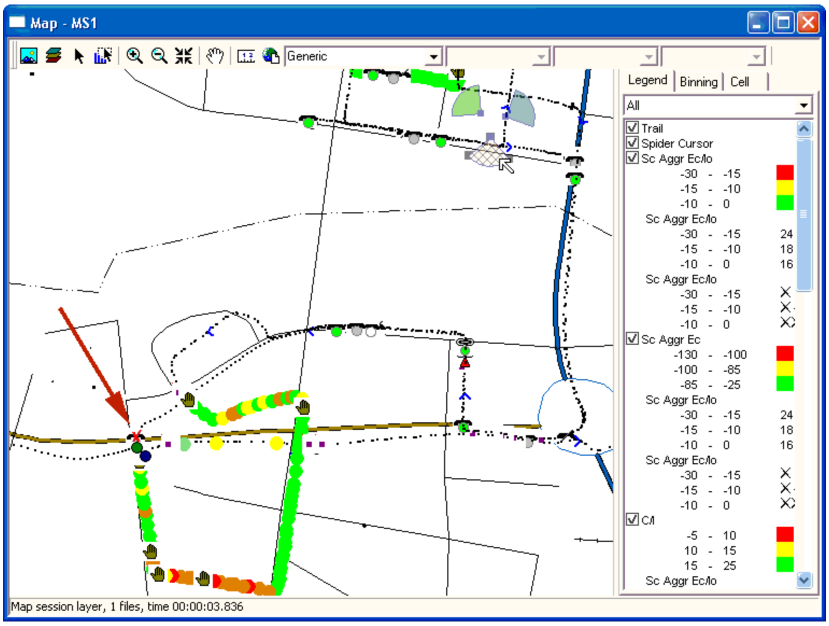
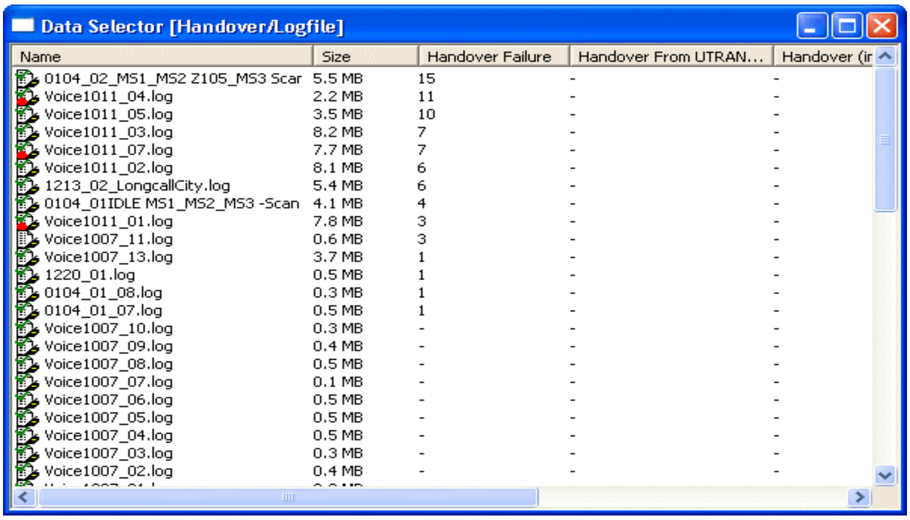


Figure 19: Call Drops Indicator

By counting failures of various types of handover, it helps track down areas (cells) infested with handover problems.

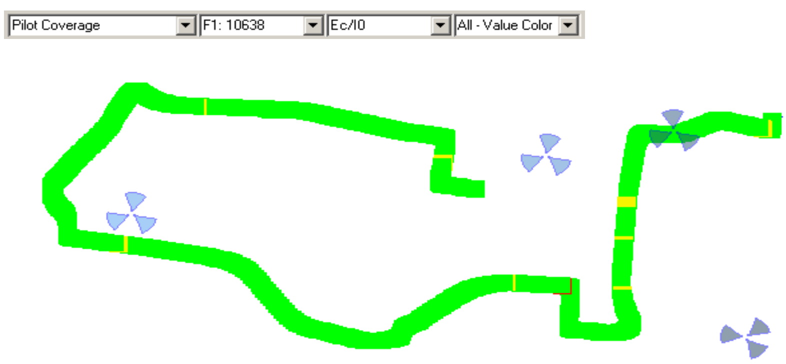


Data Selector [Handover/Logfile]

Name	Size	Handover Failure	Handover From UTRAN...	Handover (ir
0104_02_MS1_MS2 Z105_MS3 Scar	5.5 MB	15	-	-
Voice1011_04.log	2.2 MB	11	-	-
Voice1011_05.log	3.5 MB	10	-	-
Voice1011_03.log	8.2 MB	7	-	-
Voice1011_07.log	7.7 MB	7	-	-
Voice1011_02.log	8.1 MB	6	-	-
1213_02_LongcallCity.log	5.4 MB	6	-	-
0104_01IDLE MS1_MS2_MS3 -Scan	4.1 MB	4	-	-
Voice1011_01.log	7.8 MB	3	-	-
Voice1007_11.log	0.6 MB	3	-	-
Voice1007_13.log	3.7 MB	1	-	-
1220_01.log	0.5 MB	1	-	-
0104_01_08.log	0.3 MB	1	-	-
0104_01_07.log	0.5 MB	1	-	-
Voice1007_10.log	0.3 MB	-	-	-
Voice1007_09.log	0.4 MB	-	-	-
Voice1007_08.log	0.5 MB	-	-	-
Voice1007_07.log	0.1 MB	-	-	-
Voice1007_06.log	0.5 MB	-	-	-
Voice1007_05.log	0.5 MB	-	-	-
Voice1007_04.log	0.5 MB	-	-	-
Voice1007_03.log	0.3 MB	-	-	-
Voice1007_02.log	0.4 MB	-	-	-

Figure 133: Data Selector (Handover)

- . / +0' 1+



9" .6(.6(#4(0' @4#' 5(ABCD(B0E&' #1&($-0%

Figure 134: Converge

Pilot coverage is classified based on the Ec/No and RSCP readings. Four coverage levels are distinguished, numbered 1 through 4. The thresholds set in this step define transitions between levels. For each parameter, three thresholds are set: “High”, “Medium”, and “Low”.

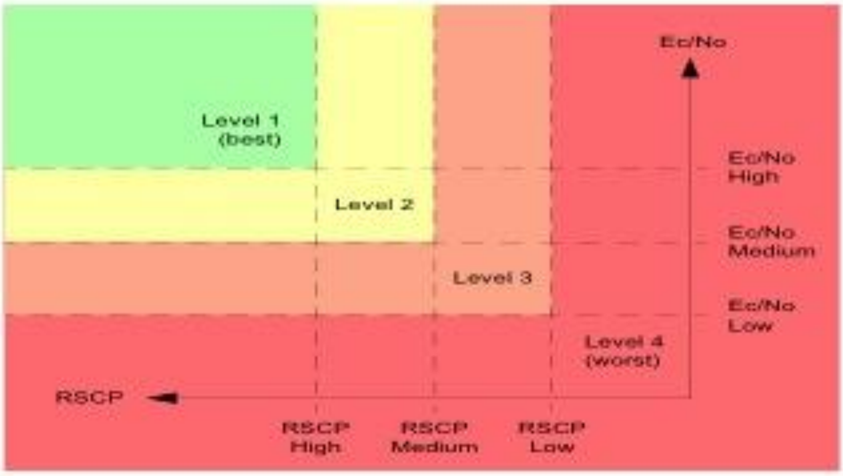


Figure 135: Coverage Levels

Table 6: Dropped calls classifications

Condition	Dropped Call Classification
(RxLev < DropRxLev) AND (Channel Release not received)	Downlink Coverage (Low signal strength)
(RxLev ≥ DropRxLev) AND (Channel Release not received)	Downlink Quality
(TA ≥ DropTA) AND (Channel Release received)	Timing Advance
(TA < DropTA) AND (RxLev < DropRxLev) AND (Channel Release received)	Uplink Coverage
(TA < DropTA) AND (RxLev ≥ DropRxLev) AND (Channel Release received)	Uplink Quality
Data insufficient to determine if any of the above classification criteria is fulfilled	No Data
None of the above criteria fulfilled	Not Classified

-END OF THESIS-