IMPLEMENTATION OF INTERFERENCE MANAGEMENT ALGORITHMS IN THIRD GENERATION NETWORKS

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ABSTRACT

IMPLEMENTATION OF INTERFERENCE MANAGEMENT ALGORITHMS IN THIRD GENERATION NETWORKS

As a rapidly growing network UMTS, the 3^{rd} generation mobile communication system, is designed to provide sufficient capacity for the services requiring high bit rates. The WCDMA technology has been chosen for the technique of UMTS in which all connections are able to use the same frequency band and time thanks to orthogonal and pseudorandom codes. As a result of using the same frequency band, interference management is a key in optimizing the network capacity and coverage. Therefore, a practically applicable algorithm is needed. However, the existing algorithms generally present iterative methods which are difficult to be applied for mobile network operators in that iterative methods require more man power and increase costs.

In this thesis, we present a two-step method that will decrease interference in UMTS Networks according to received power measurement results and network initial configuration by adapting antenna tilt, azimuth and Common Pilot Channel (CPICH) power since those parameters have direct impact on coverage area in terms of shape and size. First step calculates base stations antenna downtilt and CPICH power while second step adopting azimuths. The performances of proposed algorithms are obtained considering practical scenarios. The results have shown that antenna tilt, pilot power and azimuth can be used successfully in managing interference for UMTS Networks.

ÖZET

ÜÇÜNCÜ NESİL AĞLARDA GİRİŞİM YÖNETİMİ ALGORİTMALARININ UYGULANMASI

Hızla büyümekte olan 3. nesil mobil iletişim sistemi UMTS, yüksek hız gerektiren servisler için yeterli kapasite sağlamak üzere tasarlanmıştır. WCDMA teknolojisini kullanan söz konusu sistemde aynı frekans bandı ve aynı zaman dilimini kullanan farklı bağlantılar, dikgen ve rasgele kodlar aracılığı ile birbirinden ayrıştırılarak iletişimi sağlamaktadır. Bu nedenle girişim yönetimi ağ kapasite ve kapsamasının eniyilenmesinde önem kazanmakta ve pratik sistemlerde uygulanabilecek bir algoritmaya gereksinim duyulmaktadır. Ancak var olan algoritmalar incelendiğinde tekrarlamalı yöntemlerin kullanıldğı görülmektedir. Ancak, tekrarlamalı yöntemler uygulama aşamasında yüksek iş gücü ve maliyet gerektirmektedir. .

Uygulanabilirliği artırmak amacı ile bu tezde 3. nesil ağlarda girişim seviyesini azaltmak üzere iki adımdan oluşan bir algoritma sunulmuştur. Önerilen algoritmada veri olarak sürüş testinde elde edilen sinyal seviyesi ölçümleri ve başlangıç konfügirasyonu kullanılmıştır. Birinci adımda kapsama alanı üzerinde doğrudan etkiye sahip olmaları nedeni ile baz istasyonlarının anten eğimleri ve pilot sinyal çıkış güçleri hesaplanırken ikinci adımda ise azimutları hesaplanmaktadır. Önerilen algoritmaların performans sonuçları pratik uygulamalar göz önüne alınarak elde edilmiştir. Sonuçlar göstermektedir ki belirtilen parametreler girişim yönetiminde etkin bir biçimde kullanılabilmektedir.

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ABBREVATIONS

3GPP	3^{rd} Generation Partnership Project
8-PSK	8 Phase Shift Keying
AuC	Authentication Center
BCR	Blocked Call Rate
BTS	Base Transceiver Station
CDR	Call Drop Rate
CN	Core Network
CPICH	Common Pilot Channel
CS	Circuit Switch
DL	Downlink
DT	Drive Testing
EDGE	Enhanced Data Rates for GSM Evolution
EIR	Equipment Identity Register
ETSI	European Telecommunications Standards Institute
FDD	Frequency Division Duplex
GGSN	Gateway GPRS Service Node
GMSC	Gateway MSC
GPRS	General Packet Radio Service
GRT	General Ray Tracing
GSM	Global System for Mobile Communications
GTD	Geometrical Theory of Diffraction
HLR	Home Location Register
HSCSD	High Speed Circuit Switched Data
IMT	International Mobile Telephony
IRAT	Inter Radio Access Technology
KPI	Key Performance Indicator
LOS	Line of Site
LTE	Long Term Evolution
MIMO	Multiple-Input Multiple-Output
MMS	Multimedia Message Service
MRC	Maximum Ratio Combining

MP	Measurement Point
MSC	Mobile Switching Center
OMC	Operation and Maintenance Center
OVSF	Orthogonal Variable Spreading Factor
PCPICH	Primary CPICH Power
PDP	Packet Data Protocol
PS	Packet Switch
PSC	Primary Scrambling Code
QF	Quality Factor
QoS	Quality of Service
RET	Remote Electrical Tilt
RF	Radio Frequency
RNC	Radio Network Controller
RSCP	Received Signal Code Power
RSSI	Received Signal Strength Indicator
SGSN	Serving GPRS Service Node
SINR	Signal to Interference plus Noise Ratio
SIR	Signal to Interference Ratio
SMS	Short Message Service
TDD	Time Division Duplex
TTT	Time to Trigger
UARFCN	UTRA Absolute Radio Frequency Channel Number
UE	User Equipment
UL	Uplink
UMTS	Universal Mobile Telecommunications System
UTRAN	Universal Terrestrial Radio Access Network
USB	Universal Serial Bus
USIM	UMTS Subscriber Identity Module
VLR	Visitor Location Register
VSWR	Voltage Standing Wave Ratio
WCDMA	Wideband Code Division Multiple Access

CHAPTER 1

INTRODUCTION

This chapter gives a brief overview of the evolution to the 3rd generation networks. It provides also the scope and motivation of the thesis. After that the layout of the work is presented.

1.1 Overview and Motivation

Universal Mobile Telecommunications System (UMTS) Networks are still being deployed especially in undeveloped and developing countries. Even though Long Term Evolution (LTE) is developed and started to be used, UMTS deployment process is still ongoing and therefore it is important to be focused on.

As in all communication systems, providing the best quality of service with the cheapest possible cost is needed by mobile telecommunication operators. To achieve this hard task, commercial limitations are not the only issue to cope with. It is also important to consider technical limitations and constraints. In this respect, the efficient use of sources comes into prominence.

As will be described in the next sections, in UMTS the same frequency band is used by many users at the same time. As a result of this, interference is one of the most challenging parts of network implementation. In order to minimize the interference, the following planning and optimization parameters are mostly used in UMTS; site position, number of sectors in the site, sector azimuths, sector tilts and Common Pilot Channel (CPICH) power of the site. Azimuth describes the angle of the sector to North. Likewise, tilt is the slope of the antenna and expressed as the angle to the ground. CPICH is the pilot power used by the user equipment in idle mode to be connected to the network. In this respect, CPICH power determines the coverage.

Choosing the site positions is the part of the initial roll-out and has constraints; first, Global System for Mobile Communications (GSM) Base Transceiver Station (BTS) sites are used primarily since it costs less for the operator because of the fact that there will be no extra leasing and roll-out cost. If a new site is necessary, two or more possible locations are chosen and it is possible to face with expensive leasing cost. Second, it is decided how many sector will be used in that site according to physical conditions. Next, the azimuths and tilts of those sectors are chosen by intuitive methods first. These azimuths and tilts, later, are tuned heuristically according to drive test results and statistics. Drive test is a method to measure the quality of signal and explained in section 3.6. Power is generally used with default or maximum value first and can be changed if needed.

As can be seen, all these parameters mentioned above are about efficient use of air interface capacity which is the limiting factor of the all wireless systems when the area to be covered is large. Tuning such large area networks with this heuristic method brings about extra cost in terms of labor force and time. In this heuristic method, it is needed to make drive tests, take statistics, review the results and make decisions. Also, since the decisions may not be true, all these tasks should be done more than one time.

In this thesis, an algorithm shall be described to adjust antenna tilt, azimuth and CPICH power in two steps.

Adjusting the antenna tilt not only maximizes the link gain on its own traffic, but also lessens interference on other cells providing less required transmit power. From the perspective of cost, quality, and interference, power should be used efficiently. Lastly, Azimuth has effects on interference, coverage area, and capacity.

1.2 Structure of the Dissertation

The thesis is composed by five chapters. Firstly, the background information about UMTS including deployment, planning and optimization process is introduced. Next, the approaches in the literature are discussed by classifying in main titles. After that the proposed algorithm is introduced and the simulation results are discussed.

In Chapter 2, an introduction to UMTS and wireless channels are given including basic aspects of UMTS such as network elements, functions. After that, wireless channels is briefly explained especially in Ray Trace modeling since the simulator used in the thesis is using three dimensional ray tracing based channel modeling.

In Chapter 3, planning and optimization techniques for UMTS are introduced in physical configuration and parameter aspects. Moreover, main vision algorithms to optimize radio resources are explained. It is seen that generally four different approaches are used together; traffic load balance, self-optimizing networks, iterative methods and location advising methods.

In Chapter 4, the proposed algorithm and simulation scenarios are explained in details. Simulation results are also illustrated in this chapter.

Chapter 5 is reserved for the conclusion of the dissertation and the future works are listed.

CHAPTER 2

UNIVERSAL MOBILE TELECOMMUNICATION SYSTEM BASICS

In this chapter, a brief history of UMTS, its basics, summary of the principles, and an introduction to wireless channels will be given.

2.1 Brief History

The GSM, widely used second generation telecommunication system, enabled voice and data traffic to go on air interface with a universal accordance. Taking the advantages of universal accordance such as international call possibility and large market, the number of subscribers is increased enormously.

However, the data handling capabilities of GSM is not sufficient even though General Packet Radio Service (GPRS) and Enhanced Data Rates for GSM Evolution (EDGE) released because of the bandwidth limitations [16]. Table 1 illustrates the throughput requirements for different services.

Table 1. Throughput requirements for different services supported by GPRS and EDGE [22]

Service	Throughput Requirement
Microbrowsing (e.g. WAP)	8 to 16 kbps
Multimedia messaging	8 to 32 kbps
Video telephony	64 to 384 kbps
General purpose web browsing	32 to 384 kbps
Enterprise applications, including e-mail, database access, virtual private networking	32 to 384 kbps
Video and audio streaming	32 to 384 kbps

In 1990, GSM is released as a replacement for first generation (1G) analog cellular networks and described a digital, circuit switched network aimed to serve voice call and 9.6 kbps data services with a global standard by European Telecommunications

Standards Institute (ETSI). Due to the limited bandwidth the system capacity is enhanced constantly. The GSM uses 200 kHz frequency channels assigned to each cell. Each frequency channel is divided to 8 time slots. Time slots are used for different aims such as broadcast, common or dedicated channels.

The first extension of the GSM is High Speed Circuit Switched Data (HSCSD). By using a new channel coding method, the data rate is increased from 9.6 to 14.4 kbps. Moreover, in data services, 4 time slots from different frequency channels are bundled when available reaching 57.6 kbps data rates. In contrast to HSCSD, GPRS is packet switched in which radio resources are used only if data is being transferred. Thus, billing information is based on transmitted data, not on the connection duration. In GPRS, the data rate of each timeslot is increased again to 21.4 kbps. Bundling up to 8 timeslots, the data rate is reached to 171.2 kbps. The last extension of the GSM is EDGE which is a technology focused on the air interface between the mobile and the base station changing the modulation process. Using 8 Phase Shift Keying (8-PSK), the data rate is increased up to 474 kbps. To achieve this data rate, it is necessary to use sufficient number of base stations and careful RF planning.

As for data rates, GPRS and EDGE can achieve required throughputs for services shown in Table 1. However, when the number of users is increased, the data rates of the users will be decreased due to the limited bandwidth. Therefore, a new technology having larger bandwidth with efficient usage is required.

When UMTS was first released as a component of International Telecommunication Union IMT-2000 (International Mobile Telephony 2000) [1], its data rate was maximum 2 Mbps. After, 3rd Generation Partnership Project (3GPP) released HSPA+ which is also called 3.5G allowing users up to 84 Mbps download combining multicarrier and Multiple-Input Multiple-Output (MIMO) technologies in 10 MHz bandwidth.

UMTS uses CDMA technology evolved to be used on wideband, called WCDMA. The technology is based on codes providing using the same frequency and time domain that data packets are distinguished by codes.

To expand coverage of UMTS Networks, base stations for different physical areas are developed such as microcell or indoor cells resulting in different channel properties. In Table 2, channel characteristics for different propagation environments are shown.

Table 2. Characteristics for different propagation environments

	Delay, μs	Coherence Bandwidth, MHz
Urban	0.5	0.32
Rural	0.1	1.6
Hilly	3	0.053
Microcellular	< 0.1	> 1.6
Indoor	< 0.01	> 16

2.2 Wireless Channels

Wireless channels pose lots of challenges for high speed communications. These are not only noise and interference but also their variability with an unpredictable way due to the changes in channel. Therefore, it is crucial to understand the behavior of a transmitted signal in medium which depends on path loss, shadowing, multipath, and Doppler Effect. In this section, these concepts shall be described.

2.2.1 Free-Space Path Loss

It is the loss of signal in a straight line from the transmitter to receiver between which there is no obstacles. This channel model is called line-of-sight (LOS), and the signal through this channel called LOS signal. Path Loss is defined as

$$P_L(dB) = P_t(dB) \; - P_r(dB) \tag{2.1}$$

where P_t is the transmitted signal power and P_r is the received signal power. The path loss itself depends on wavelength of the transmitted signal, transmit and receive antenna pattern product and distance as given below,

$$\frac{P_r}{P_t} = \left[\frac{\sqrt{G}\,\lambda}{4\pi d}\right]^2 \tag{2.2}$$

where G is the transmit and receive antenna pattern product, λ is wavelength of the transmitted signal, and d is the distance between transmit and receive antenna [5].

2.2.2 Shadow Fading

In a wireless channel, a transmitted signal will experience random blockages in its paths on a realistic medium which will cause random changes in the received signal power. Since it is unpredictable as a function of time, it is needed to define a statistical model. A common used model is log-normal given by

$$p(\psi_{dB}) = \frac{\xi}{\sqrt{2\pi}\sigma_{\psi_{dB}}} exp\left[-\frac{(\psi_{dB} - \mu_{\psi dB})^2}{2\sigma^2_{\psi_{dB}}}\right] \quad (2.3)$$

where $\xi = 10/ln10$, $\mu_{\psi dB}$ is the mean of ψ_{dB} in dBs, and $\sigma_{\psi dB}$ is the standard deviation of ψ_{dB}. The mean and variance of this Gaussian can be found by using empirical measurements [5].

2.2.3 Doppler Shift

Another issue in wireless channels is the mobility of transmitters and receivers. A small change in the distance in a short time interval makes the signal propagate more than expected. During this small propagation, a phase shift occurs and results a change in frequency. In UMTS, a mobile travelling around at a speed of 100 km/hr will face with approximately 200 Hz Doppler shift. The frequency shift can be calculated as

$$f_D = \frac{v}{\lambda} cos\emptyset_{D_n} \quad (2.4)$$

where v is speed in m/s, λ is wavelength in meters, and $\emptyset_{D_n}$ is the arrival signals angle to the ground. If receiver is in opposite way of arrival signal, then frequency is positive, otherwise it is negative as a result of its geometry [5].

2.2.4 Multipath Channels

In a wireless channel, different multipath components occur as shown in Figure 1. In this section, a random time-varying impulse response for a multipath channel shall be characterized.

When a single pulse is transmitted over a multipath channel, the received signal will be an impulse train between which different time delays occur according to their path lengths. These delays shall be described according to the time delay between the corresponding and first received component. The first received component may be LOS or a multipath component [17].

It is also considerable that the multipath channels are time-varying. That characteristic is due to either mobility of transmitter or receiver. Yet, when compared to the fading due to constructive and destructive addition of multipath components, the changes in channel is much slower.

A transmitted signal can be expressed by the following formula;

$$s(t) = \mathrm{Re}\left\{u(t)e^{j2\pi f_c t}\right\} = \mathrm{Re}\{u(t)\}\cos(2\pi f_c t) + \mathrm{Im}\{u(t)\}\sin(2\pi f_c t) \quad (2.5)$$

where $u(t)$ is the lowpass signal for $s(t)$ and f_c is the carrier frequency [5]. Thus, the corresponding received signal shall be the sum of LOS and multipath components which is expressed as;

$$r(t) = \mathrm{Re}\left\{\sum_{n=0}^{L(t)} \alpha_n(t)u(t-\tau)e^{j\left(2\pi f_c(t-\tau_n(t))+\emptyset_{D_n}(t)\right)}\right\} \quad (2.6)$$

where $n = 0$ corresponds to the LOS path. $L(t)$ is the number of resolvable components, $\tau_n(t)$ time delay function equal to $r_n(t)/c$ where $r_n(t)$ is the corresponding path length and c is the speed, $\emptyset_{D_n}(t)$ is the Doppler phase shift, and $\alpha_n(t)$ is the amplitude [5]. Two multiple component is said to be resolvable if the time delay between them $(\tau_{n+1} - \tau_n)$ are much larger than the inverse bandwidth of the corresponding signal.

Figure 2 shows model for time variant channel where $c_i(t)$ represents tap coefficient where $i = 1,2, \dots, L$. We may express each time coefficient as

$$c(t) = c_r(t) + jc_i(t) \tag{2.7}$$

where $c_r(t)$ and $c_i(t)$ represent real-valued Gaussian random processes. It is assumed that $c_r(t)$ and $c_i(t)$ are stationary and statistically independent. $c(t)$ also can be expressed in the form as

$$c(t) = \alpha(t)e^{j\emptyset(t)} \tag{2.8}$$

where

$$\alpha(t) = \sqrt{c_r^2(t) + c_i^2(t)} \tag{2.9}$$

$$\emptyset(t) = \tan^{-1}\frac{c_i(t)}{c_r(t)} \tag{2.10}$$

In this representation, if the real and imaginary components of tap coefficients are zero-mean Gaussian, the amplitude $\alpha(t)$ is Rayleigh distributed and phase $\emptyset(t)$ is uniformly distributed over the interval $(0,2\pi)$. Consequently, the channel is called Rayleigh fading channel [17].

Figure 3 depicts a hierarchical propagation channel model for multipath fading, shadowing, and path loss together. The path loss represents the mean attenuation while shadowing shows the random fading of the received power. The multipath represents the rapid fluctuation caused by a number of propagation paths interfering one another causing large variations.

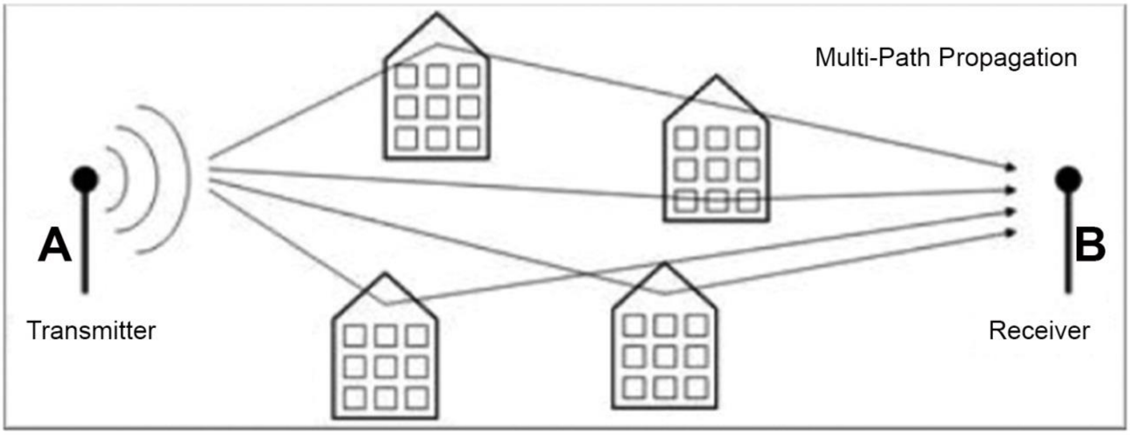

Figure 1. Presence of physical structures results in multi-path propagation [18]

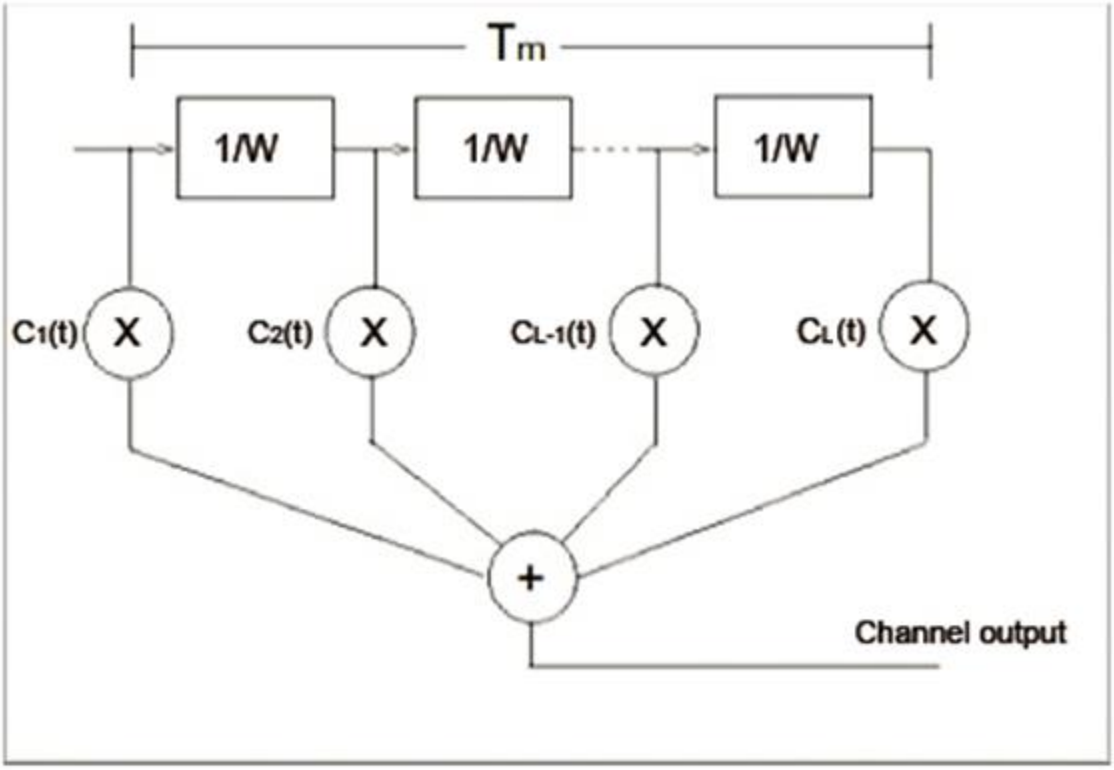

Figure 2. Model for time-variant multipath channel. W is the bandwidth and Tm is measurement period [17]

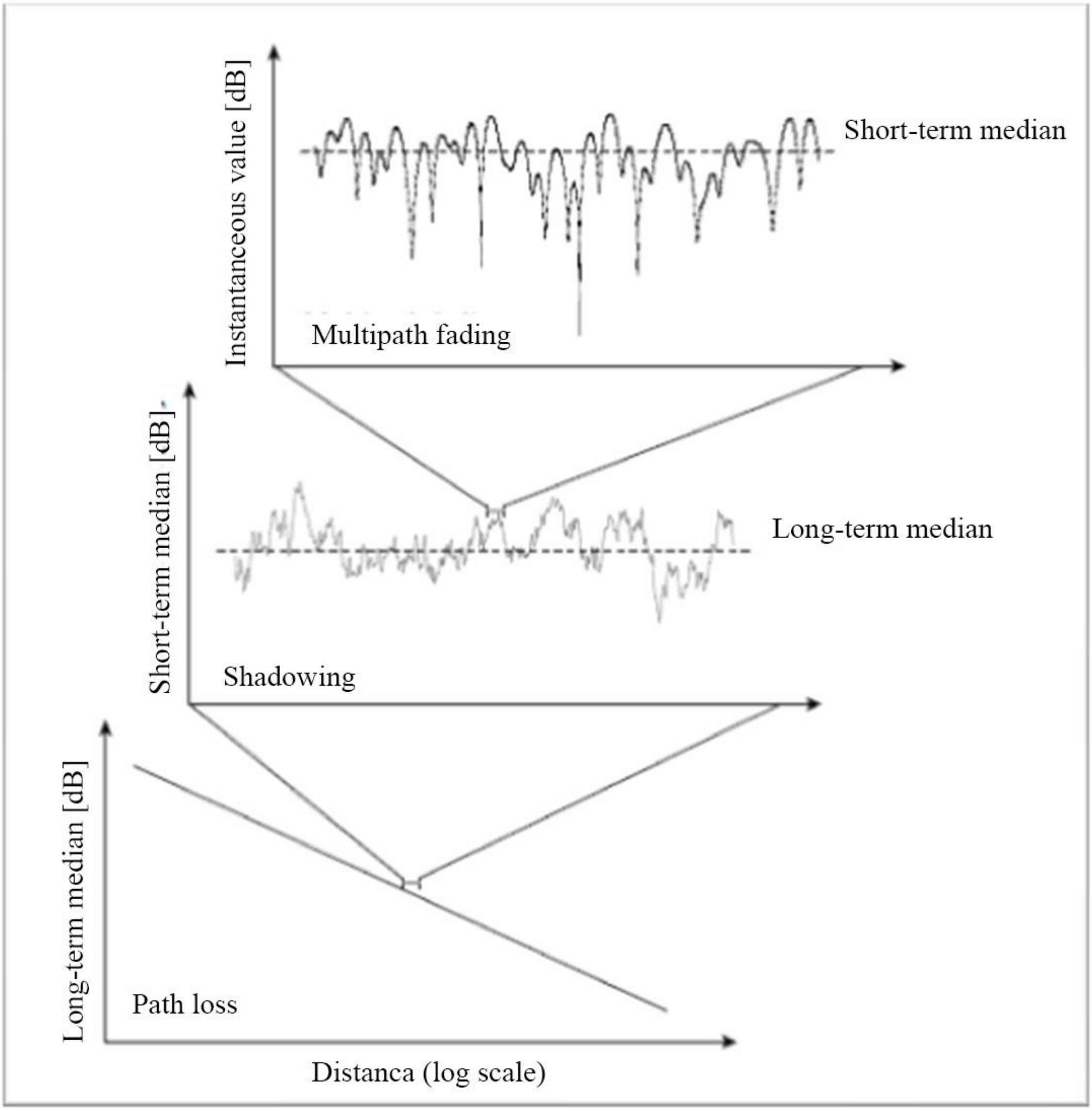

Figure 3. Hierarchical propagation channel model [23]

2.2.5 Ray Tracing

Since the simulations are implied by using ray tracing method in this work, it is essential to mention ray tracing channel modeling briefly.

In a typical medium, a radio signal encounters multiple objects and reflects, diffracts and scatters by producing lots of copies of it. These are called as multiple signal components. These components' phase, loss, and arrival time to receiver can be different than LOS signal and these differences produce distortion in the received signal. Ray tracing is a useful method for calculating the properties of those multipath components such as their paths, attenuations and phase using the exact geometric information of the physical area. In addition, the method is also used to calculate channel impulse response of wireless channels [29].

In ray tracing method, compared to multipath channel, it is assumed a finite number of multiple signal components are taken into account to reduce complexity of modeling. In this manner, Ray tracing provides easier calculation and simulation opportunity. However, reducing complexity causes loss of information resulting in approximate results.

It is prominent to note that when all the elements of the channel including transmitter and receiver are fixed, then the properties of the received signal are constant. Although, even one of them is mobile, it means that the characteristics of the received signal vary in time.

In the following subsections, two-ray, ten-ray and general ray tracing models are introduced.

2.2.5.1 Two-Ray Model

When only a ground exists between transmitter and receiver two-ray model is applied. The received signal has two components: one of them is LOS signal and the other is the one that is reflected from the ground as shown in Figure 4.

After making necessary approximations and substitutions the ratio between received and transmitted signal becomes

$$\frac{P_r}{P_t} = \left[\frac{\sqrt{G_l} h_t h_r}{d^2}\right]^2 \quad (2.11)$$

where G_l is the product of the transmitter and receivers radiation pattern, h_t is the height of the transmitter from the ground and h_r is that of receiver [5].

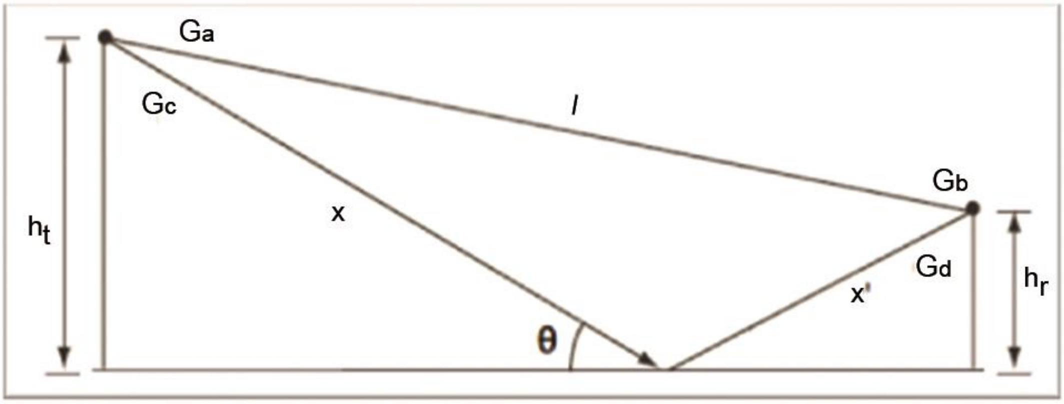

Figure 4. Two-ray model. [5]

2.2.5.2 Ten-Ray Model (Dielectric Canyon)

Two-ray model is not adequate to model complex channels. Ten-Ray model is developed to model a rectangular street where both sides covered by straight buildings from transmitter to receiver. The geometry of the model can be seen on Figure 5.

The ratio between received and transmitted signal power in Ten-Ray model is given by

$$\frac{P_r}{P_t} = \left\{{}^{\lambda}/_{4\pi}\right\}^2 \left\{\left|\frac{G_d(x)}{r} + \sum_{i=1}^{9}\left[\frac{G_{ri}(x) R_i \exp(j\phi_i)}{r_i}\right]\right|^2\right\} \quad (2.12)$$

where

$$\phi_i = \frac{2\pi(r_i - r)}{\lambda} = 2\pi\Delta l_i / \lambda \quad (2.13)$$

and r_i is the path length of the i^{th} ray, R_i is the reflection coefficient, $G_d(x)$ and $G_{ri}(x)$ are products of base and mobile antenna field radiation patterns corresponding to the paths of the direct and i^{th} reflected rays with the corresponding proper transmission and arrival angles [6].

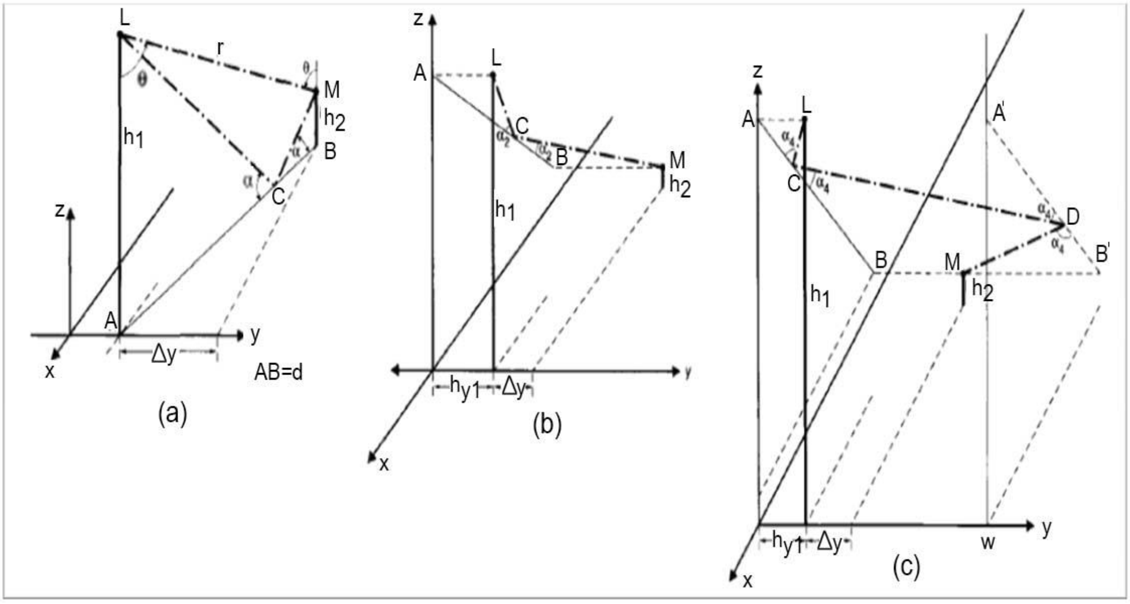

Figure 5. Reflection models (a) direct and ground reflection, (b) single wall reflection, (c) double reflection [6]

2.2.5.3 General Ray Tracing

Two-Ray and Ten-Ray tracing models are used for specific areas. However, General Ray Tracing (GRT) can be used for any site configuration by giving the information of the area to predict delay spread and strength of the received signals.

In GRT method, Geometric optics is used to trace the LOS signal, reflected signals, components from diffractions and diffuse scattering. As in Two-Ray and Ten-Ray method, the strength and delay of each component of the transmitted signal are calculated separately. Generally, LOS and reflected paths dominate, even though in close areas to the scattering and diffraction surfaces, it is possible that other components dominate.

Diffractions occur when a signal passes so close to edge of an obstacle that it is bended around. The geometrical behavior of diffraction is explained accurately by the geometrical theory of diffraction (GTD) [7]. Since GTD is hard to apply, it is simplified by assuming all objects as wedge. However, this simplified model requires a numerical solution. Therefore, Fresnel knife edge diffraction model which assumes the diffracting objects asymptotically thin and does not use diffractor parameters such as polarization, conductivity, and surface roughness leading inaccuracies is used commonly thanks to its simplicity on calculation. The geometry of this model is shown in Figure 6.

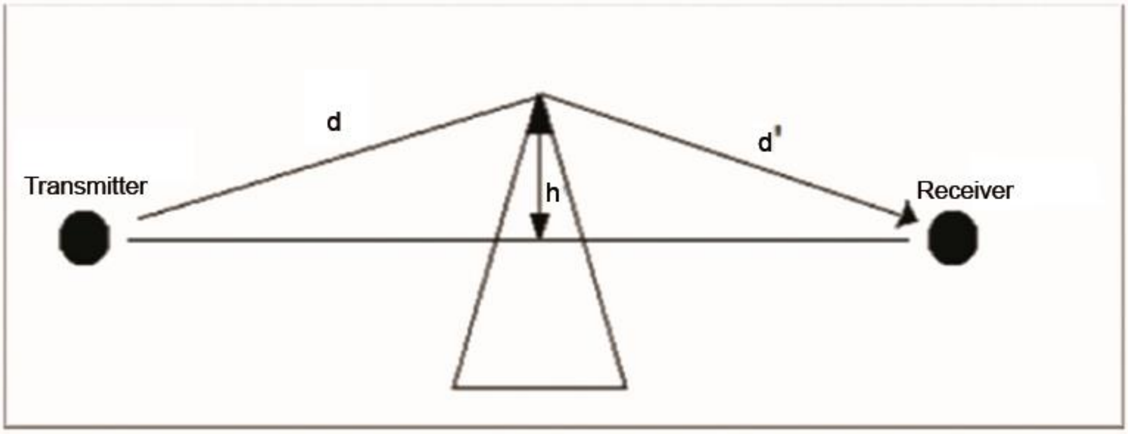

Figure 6. Knife-edge diffraction [5]

Since the total distance of transmitted signal is $d + d'$, then the phase shift becomes $2\pi(d + d')/\lambda$ where λ is the wavelength. For a small height h relative to d and d', the diffracted signal goes an additional distance compared to LOS signal and this is approximately

$$\Delta d \approx \frac{h^2}{2}\frac{d + d'}{dd'} \tag{2.14}$$

Then, the corresponding phase shift relative to LOS signal is approximately

$$\Delta\phi = \frac{2\pi\Delta d}{\lambda} \approx \frac{\pi}{2}v^2 \tag{2.15}$$

where

$$v = h\sqrt{\frac{2(d + d')}{\lambda d d'}} \tag{2.16}$$

and v is called Fresnel-Kirchhoff diffraction parameter. v is important since the path loss is defined as a function of v [5].

Lastly, scattering signals should be considered. As can be seen in Figure 7, A scattered ray's path length is $s + s'$. The received signal power function of a scattered signal is given by bistatic radar equation [5]. Thus, a received signal having LOS signal, N_r reflected, N_d diffracted, and N_s scattered rays can be defined as

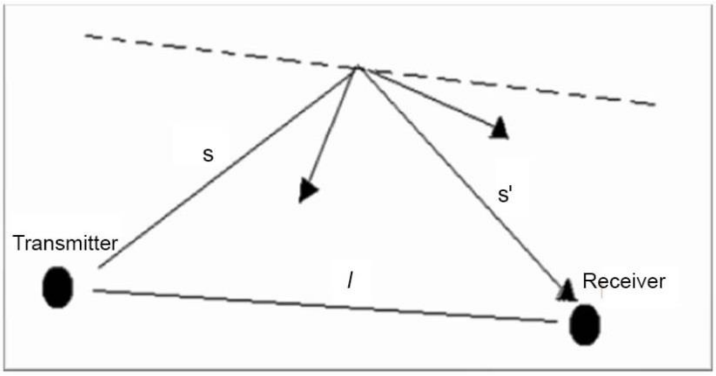

Figure 7. Scattering. [5]

$$r_{total}(t) = Re\left\{\left[\frac{\lambda}{4\pi}\right]\left[\frac{\sqrt{G_l}u(t)e^{\frac{j2\pi l}{\lambda}}}{l} + \sum_{i=1}^{N_r}\frac{R_{x_i}\sqrt{G_{x_i}}u(t-\tau_i)e^{-\frac{2j\pi x_i}{\lambda}}}{x_i} + \sum_{j=1}^{N_d}\frac{4\pi}{\lambda}L_j(v)\sqrt{G_{d_j}}u((t-\tau_j)e^{-2j\pi(d+d')/\lambda} + \sum_{k=1}^{N_s}\frac{\sqrt{G_{s_k}\sigma_k}u(t-\tau_k)e^{-2j\pi(s_k+s_k')/\lambda}}{\sqrt{4\pi s_k s_k'}}\right]e^j 2\pi f_c t\right\} \tag{2.17}$$

where $u(t)$ is the transmitted signal and τ_i, τ_j, τ_k are respectively the time delays of reflected, diffracted and scattered rays normalized to the LOS ray. N_r, N_d, and N_s are the number of reflected, diffracted and scattered rays. G_l, G_{x_i}, G_{d_j}, and G_{s_k} are the antenna pattern products for LOS, reflected, diffracted, and scattered rays respectively. l, x, $(d + d')$, and $(s_k + s'_k)$ are the path lengths for LOS ray, reflected rays, diffracted rays and scattered rays respectively. f_c is the carrier frequency and λ is the wavelength. $L_j(v)$ is the Lee function which is the approximation for the knife-edge diffraction path loss relative to LOS path loss.

2.3 Introduction to UMTS

In this section, network architecture, frequency spectrum and air interface properties of UMTS networks will be introduced.

2.3.1 Network Architecture

UMTS Networks have two parts: Core Network (CN) and Universal Terrestrial Radio Access Network (UTRAN). CN is responsible for the connections in UMTS Network and UTRAN is responsible for air interface to be used by user equipment. These two parts are connected with an interface called Iu as shown in Figure 8.

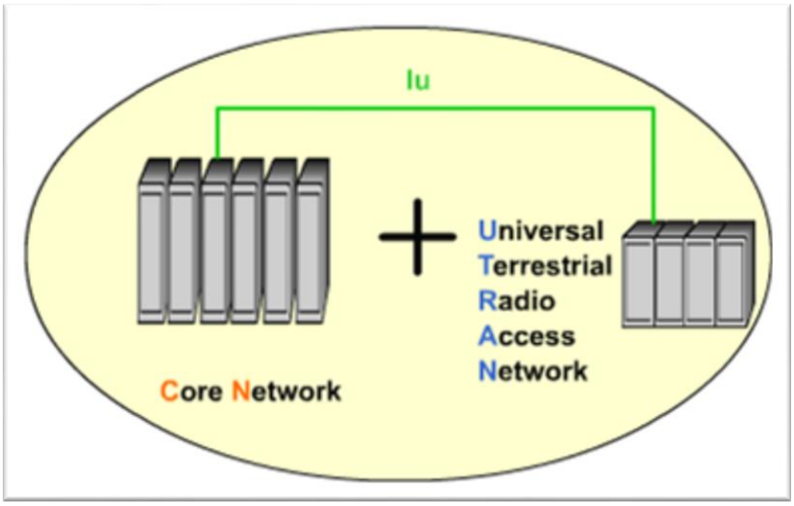

Figure 8. CN, UTRAN and Iu interface [3]

Since the UMTS networks work parallel with GSM networks, Iu interface have the responsibility to connect UTRAN not only to Packet Switched (PS) CN but also to Circuit Switched (CS) CN. These are called Iu PS and Iu CS respectively as shown in Figure 9. It also allows different manufacturers to be used under same CN. The other interfaces that are shown in Figure 9 are respectively Cu interface that is responsible for the connection between Mobile Equipment (ME) and UMTS Subscriber Identity Module (USIM), Uu interface which provides the connection between User Equipment (UE) and UTRAN, Iub interface that is in charge of connection between Node Bs and Radio Network Controllers (RNCs), and Iur interface which connects RNCs to each other.

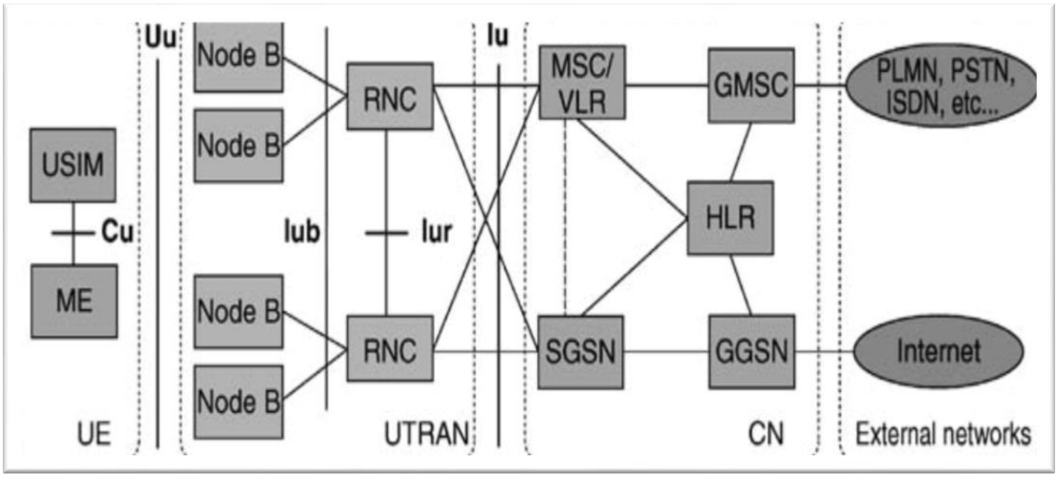

Figure 9. UMTS topology with interfaces [1]

The network elements of UTRAN and CN are described in the following:

User Equipment(UE) is the device that is able to connect UTRAN over Uu interface.

UMTS Subscriber Identity Module (USIM) keeps user specific information for encryption and authentication.

Node B connects Iub and Uu interfaces by converting the data flow each other. Moreover, it has role in radio resource management.

Radio Network Controller (RNC) manages radio resources, a part of mobility functions, and encryptions of user data for Node Bs connected to it.

Home Location Register (HLR) is a database that keeps users' service profile and location history of User Equipment.

Equipment Identity Register (EIR) checks equipment's identities to control whether the equipment is registered or not.

Authentication Center (AuC) checks SIM cards if they belongs to the operator or not.

Mobile Switching Center (MSC) serves UEs and switches CS transactions. It works parallel with Visitor Location Register (VLR).

Visitor Location Register (VLR) saves the current location and a part of user profile information of UEs and shares this information with MSC.

Gateway MSC (GMSC) connects CS domain services to external networks like PSTN.

Serving GPRS Support Node (SGSN) works similar to MSC but operates for PS domain services. That is, it is responsible for the delivery of data packets from and to the mobile stations.

Gateway GPRS Support Node (GGSN) works similar to GMSC but operates for PS domain services. It is responsible for the internetworking between the GPRS network and external packet switched networks

2.3.2 Core Network (CN)

Core Network has three domains; Circuit Switched, Packet Switched, and Register and Service domains.

Circuit Switched domain is the part that manages compatible working with GSM and includes an adapted version of Mobile Switching Center(MSC), Gateway MSC, and Visitor Location Register (VLR) from GSM.

Packet Switched domain has the same tasks of MSC but for packet data. The nodes in PS domain are Serving GPRS Support Node (SGSN) including VLR and GGSN that connects CN to other packet switched networks like internet.

The Register Domain consists of the HLR, the EIR and the AuC. The Service Domain is used to create Value Added Services (VAS) for the users. The topology of CN can be seen in Figure 10.

2.3.3 Universal Terrestrial Radio Access Network (UTRAN)

The architecture of UTRAN is given in Figure 9 with the interface names between connected network elements. The UTRAN has two elements; Node B and Radio Network Controller (RNC).

Node B, also called Base Station or site, is the part for the communication between User Equipment (UE) and RNC. Also, it provides a part of Radio Resource Management system.

RNC is the manager of the Radio Network Subsystem which is a group of Node Bs connected to one RNC. RNC has the radio resources and controls them for UEs in order to be used effectively.

In Figure 11, network topology for a standard three-sector network topology, where a directional antenna is used for each sector, with a 3 dB beamwidth of 65 degrees is shown.

UTRAN is designed to manage the following functions; Radio Resource Control, Admission Control, Congestion Control, Code Allocation, Power Control, Handover Control, and Macro-diversity. The functions will be explained detailed in the following sections.

2.3.3.1 Radio Resource Control

Radio Resource Control (RRC) is the function that manages radio resources assigning available and appropriate resource for UE, and used during cell update, handover, and measurements. Namely, the RRC protocol is responsible for the establishment, release and configuration of radio connections between the user equipment (UE) and the mobile network (UTRAN) [19].

RRC provides three services to upper layers; *general*, *notification*, and *dedicated control*. *General* service provides broadcasting service information to all UEs while *notification* service provides broadcasting information and paging services to specific UEs. *Dedicated control* service provides services for connection establishment and release and messages during the connection [20].

It is also necessary to note that UEs are to be capable of processing several RRC procedures simultaneously due to the fact that two or more RRC procedure may apply at the same time. Therefore, after reception of an RRC message, the UE also prepares itself for another RRC procedure [24].

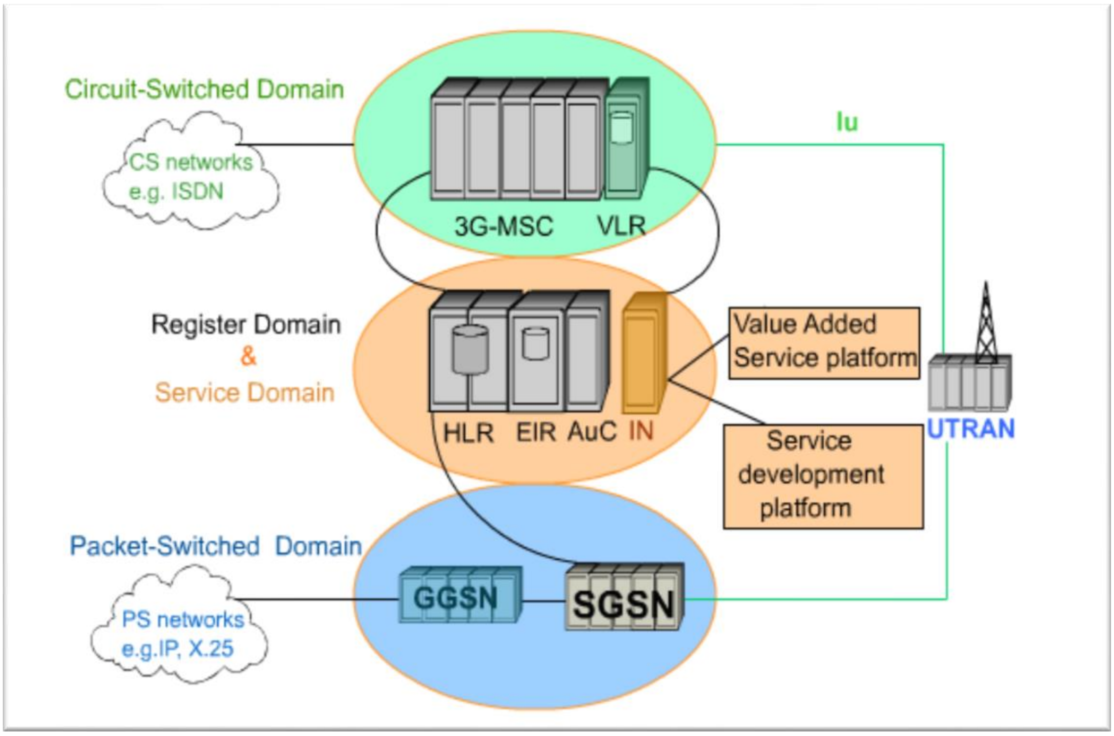

Figure 10. CN Structure [3]

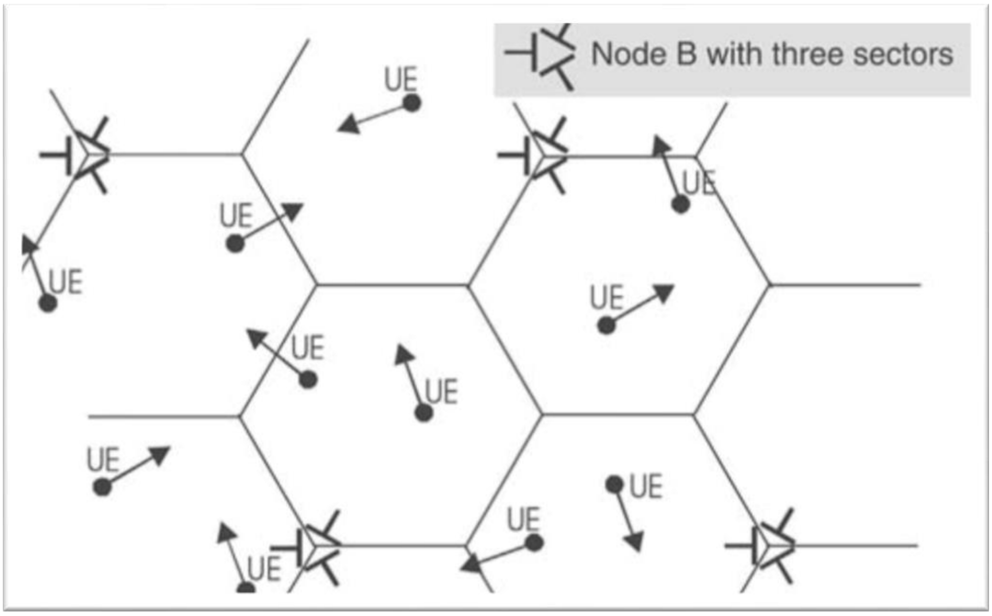

Figure 11. Network topology [1]

2.3.3.2 Admission Control

The main task of Admission Control function is to keep the quality of radio network in a predefined level. This algorithm is executed in case of setting up for a new connection or update on a service. Admission Control can deny a new UEs access to network if $\eta_{ad} \leq \eta_{max}$.

When K number of users are admitted in the system, (K+1)th user should satisfy the following condition;

$$\eta_{ad} = (1+f)\sum_{i=1}^{K}\frac{1}{\frac{SF_i}{v_i\left(\frac{E_b}{N_o}\right)_i r}+1} + (1+f)\frac{1}{\frac{SF_{K+1}}{v_{K+1}\left(\frac{E_b}{N_o}\right)_{K+1} r}+1} \leq \eta_{max} \tag{2.18}$$

where η_{ad} is load factor, f is the fraction of other-cell interference and own-cell received power, E_b/N_o is the target quality level, v_i is the activity factor of i^{th} user between 0 and 1, SF_i is the spreading factor of ith user and r is the coding rate [9].

2.3.3.3 Congestion Control

In CDMA networks, to cope with congestion situation, an algorithm should be executed to keep Quality of Service (QoS) over an acceptable value. The algorithm includes following steps:

1. Congestion detection: A criteria based on the increase of a load factor over a threshold during a specific time interval can be used to detect if there is congestion or not.
2. Congestion resolution:
   - Prioritization: ordering users from regarding to QoS requirements.
   - Load reduction:
     a. Selective blocking of new connections
     b. Reducing the maximum transmission rate
   - Load check: load reduction actions should be applied till the considered load targets are reached [26].

It is necessary to note that congestion control operates after connection while admission control provides an acceptance process to the corresponding cell.

Load factor η_{co} is described in the following formula. When the system is fully loaded, η_{co} equals to one. Since a fully loaded system may behave instable, it is necessary to use a safety margin. The load factor should be between 0.4 and 0.8 for an efficient usage.

$$1 - \eta_{co} = \frac{SIR_{loaded}}{SIR_{empty}} = \frac{\frac{S}{I_{tot}}}{\frac{S}{I_0}} = \frac{I_0}{I_{tot}} \Leftrightarrow \eta_{co} = 1 - \frac{I_0}{I_{tot}} \qquad (2.19)$$

where I_0 is the interference plus noise of the cell having no traffic, I_{total} is the total interference plus noise, S is the received power at the base station from each user, SIR is the Signal to Interference Ratio [25]. When η_{co} is larger than the safety margin, either bit rates are reduced of the users or some of the connected UEs are forced to handover or controlled tear down as shown in Figure 12.

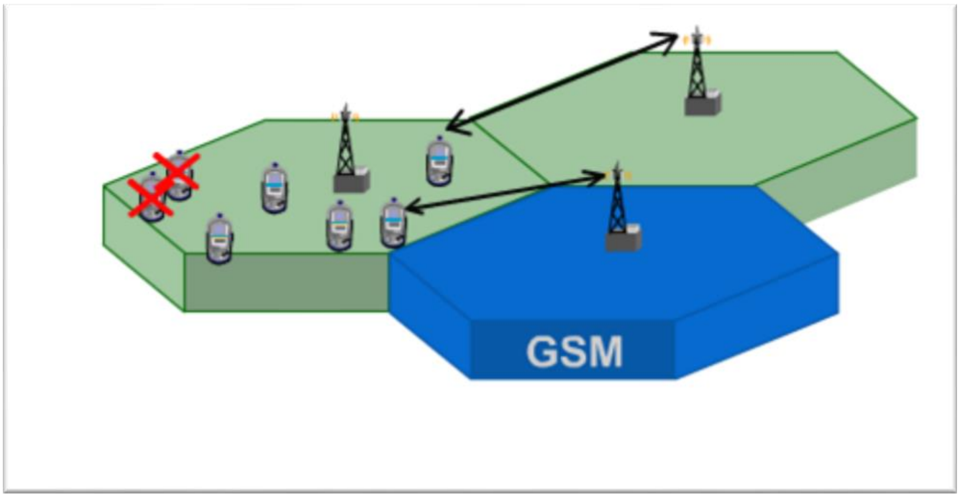

Figure 12. UEs that are forced to soft handover, hard handover and controlled tear down [3]

2.3.3.4 Code Allocation

RNCs are responsible for Code Allocation. RNC assigns codes for each connection and while doing this it considers that the assigned codes must be unique within a single cell and its neighboring cells. Code allocation is explained in section 2.3.5 more detailed.

2.3.3.5 Power Control

Another responsibility of RNCs is power control. Power control is very important for UMTS networks. Since the same frequency is used for all users, the separation between users is carried out by code division. Therefore, unnecessarily high code power will increase interference for other codes. This directly reduces capacity by affecting Signal to Interference Ratio (SIR).

If two users transmit the same power from different distances to the same Node B, the closer one will drown out the one far away from the base station on uplink channel. This is called Near-Far problem. In general meaning, near-far problem is a condition in which a receiver captures a strong signal and thereby makes it impossible for the receiver to detect a weaker signal. To avoid such situations, power control adapts the transmit powers just enough to be received by Node B. The closed loop power control tries to avoid such problems with two functions inner and outer loop power control shown in Figure 13. Inner loop power control adjust the transmit power of the UE to keep SINR equal to target while outer loop power control calculates the SIR target. Outer loop power control is a part of Radio Resource Control since targets are calculated with regard to the available radio resources [21].

Inner loop power control measures SIR values and sends them to transmitter for each time slot (10 milisecond) (i.e. uplink) for transmitter power update. According to SIR level two algorithms are applied [11].

Algorithm 1: the transmitted power is updated for each time slot with a fixed step size

$$\begin{cases} \text{decrease transmit power one step, } SIR_{est} > SIR_{target} \\ \text{increase transmit power one step, } SIR_{est} < SIR_{target} \end{cases}$$

where SIR_{est} is the estimated SIR level and SIR_{target} is the target SIR. SIR in this algorithm is defined as follow:

$$SIR = \frac{S}{I} \tag{2.20}$$

where S is the received signal from the corresponding user and I is the total received signal strength from all users.

Algorithm 2 is a reviewed version of Algorithm 1. This time the algorithm is applied per 5 time slot to decrease bandwidth used by PC. If step size for power increase and decrease is small then power control may require high bandwidth then it is proposed to select algorithm 2.

SIR targets are determined by service types and the load factor. Load factor conditions are explained in either admission control or congestion control sections. Table 3 shows the required SIR level for different service types for both Uplink (UL) and Downlink (DL).

Table 3. SIR Thresholds in dB for UMTS

	Voice	**64kbps data**	**144kbps data**	**384kbps data**
DL in dBs	-16	-11	-9	-5
UL in dBs	-18	-14	-12	-8

Power control comes into prominence in that it limits cell breathing by using radio resources efficiently. Cell breathing phenomenon briefly corresponds to coverage area changes in CDMA based networks due to the high load on base stations. Cell breathing allows overloaded cells to offload subscriber traffic to neighboring cells by changing the geographic size of their service area. This is carried out by reducing CPICH power.

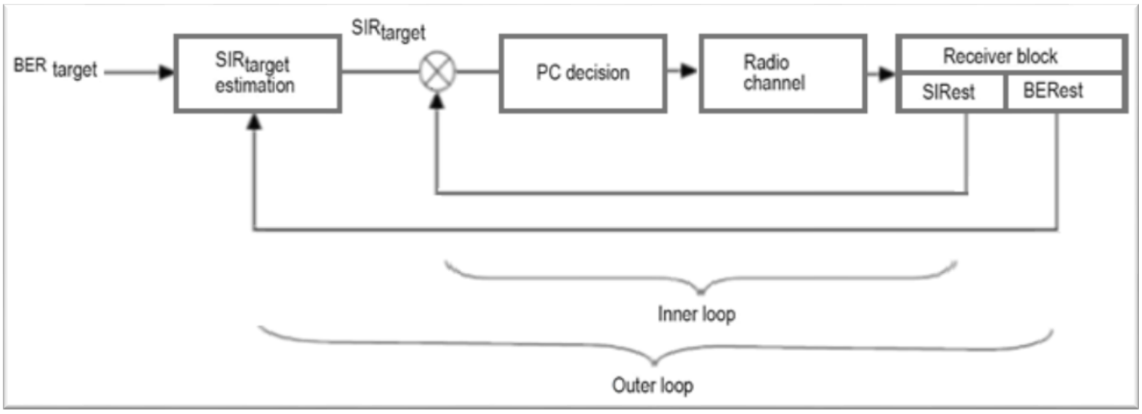

Figure 13. Closed Loop Power Control [21]

2.3.3.6 Handover

In order to keep an individual UEs connection quality over a threshold value, another function is used which is called as handover. If a connection quality reduces so much that quality goes under intended value, handover algorithm is executed and the UE changes the Node B that it connected to. There are two types of handover; soft and hard. Carrying a connection from a Node B to another is called soft handover. When this happens under the same site, this is called softer handover. If this carrying is from one frequency band to another or from UMTS to GSM, this is called as hard handover.

In a wireless network, since it requires a hard process, during a handover, drop events can occur. Therefore, it is necessary to plan a network that the number of handovers is as low as possible. This can be succeeded by adjusting the azimuths, tilts and transmit powers of cells according to the mobility of physical area.

As can be seen on Figure 14, handover process starts with RNCs measurement control message to UE. After reception of the message, UE starts performing measurement, evaluates the results and sends it to RNC. The measurement results are also evaluated by RNC. After that, when needed, RNC setups or adds a new radio link reserving it for the corresponding UE and sends the decision to UE to check. An acceptation message is sent to RNC by UE. Lastly, radio link is released and Handover process is completed. To illustrate, in Figure 15 and Figure 16 illustrates examples for Radio Link Addition and Intra-frequency handover called Event 1a and Event 1c respectively. Note that, Event 1b is the opposite version of 1a, namely used for removing a cell from Active Set (see 2.3.3.7). In Figure 15, Cell 3, Primary CPICH power (PCPICH) 3, enters the reporting range (also called active set window) at point defined as Event 1a detected. Since it stays in the interval more than Time to Trigger (TTT) parameter value, Cell 3 is started to be reported in Event 1a reports for each *Reporting interval*. The number of reports is defined by *Reporting number* parameter. Since PCPICH 3 exits from the interval before Reporting period completed, Cell 3 is not accepted to Active Set. In Figure 16, an intra-frequency handover process is illustrated. PCPICH 1 (Cell 1) is dramatically decreasing while PCIPCH 4 (Cell 4) is increasing. When they are equal, Event 1c process starts. If this situation continues for more than TTT interval, it is started to be reported for each *Reporting interval.* When the difference between PCPICH 4 and PCPICH 1 is more than hysteresis defined between Cell 1 and Cell 4, handover between them is executed.

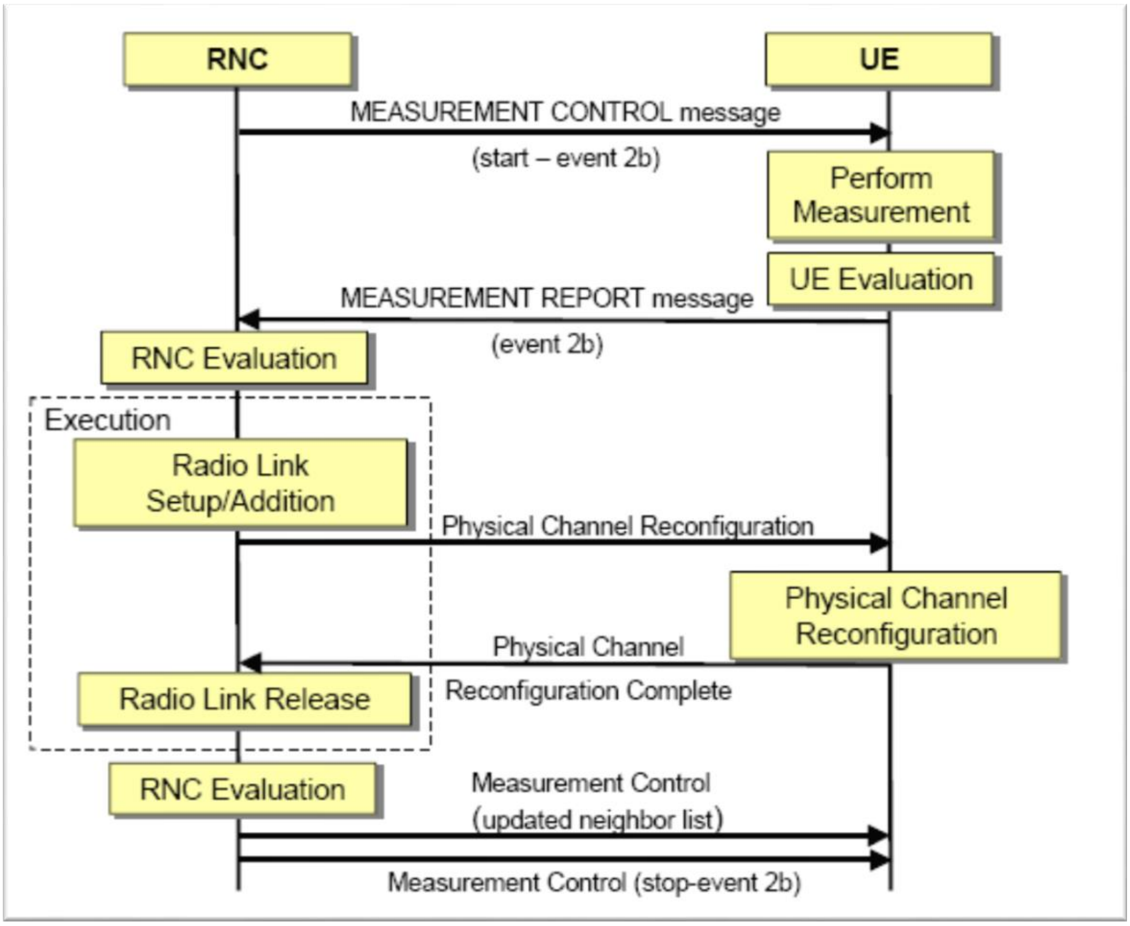

Figure 14. Intra-frequency and Inter-frequency handover

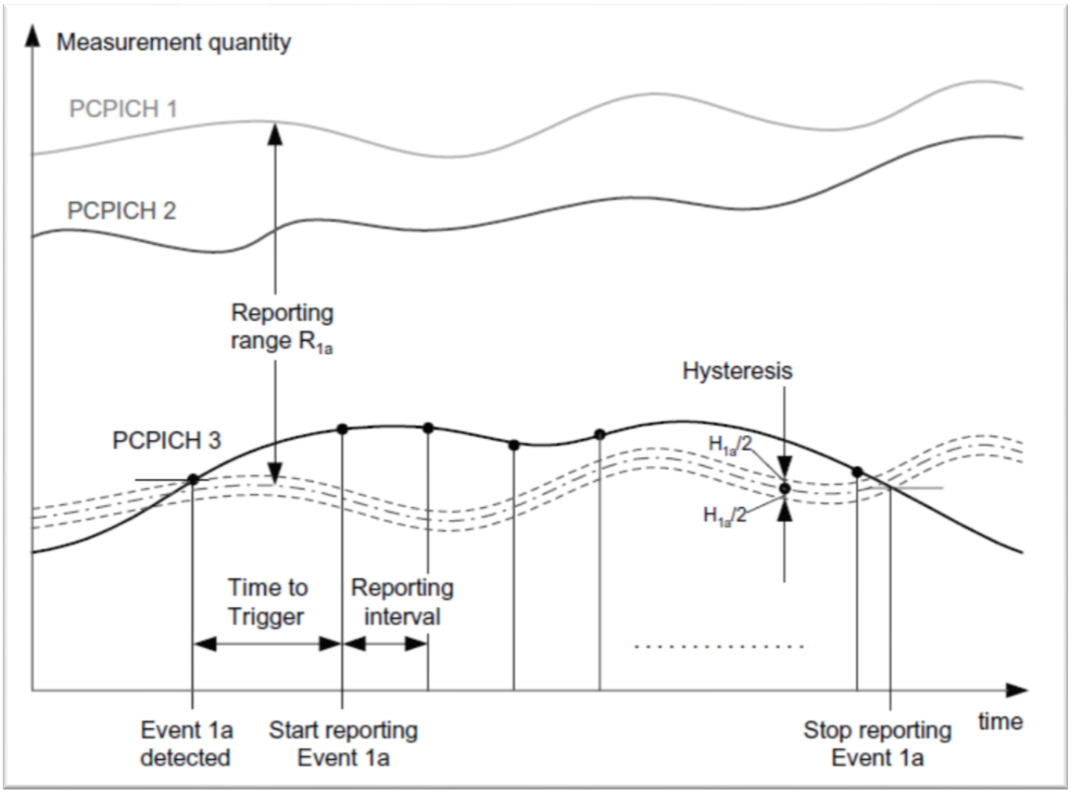

Figure 15. Event 1a, Radio Link Addition [4]

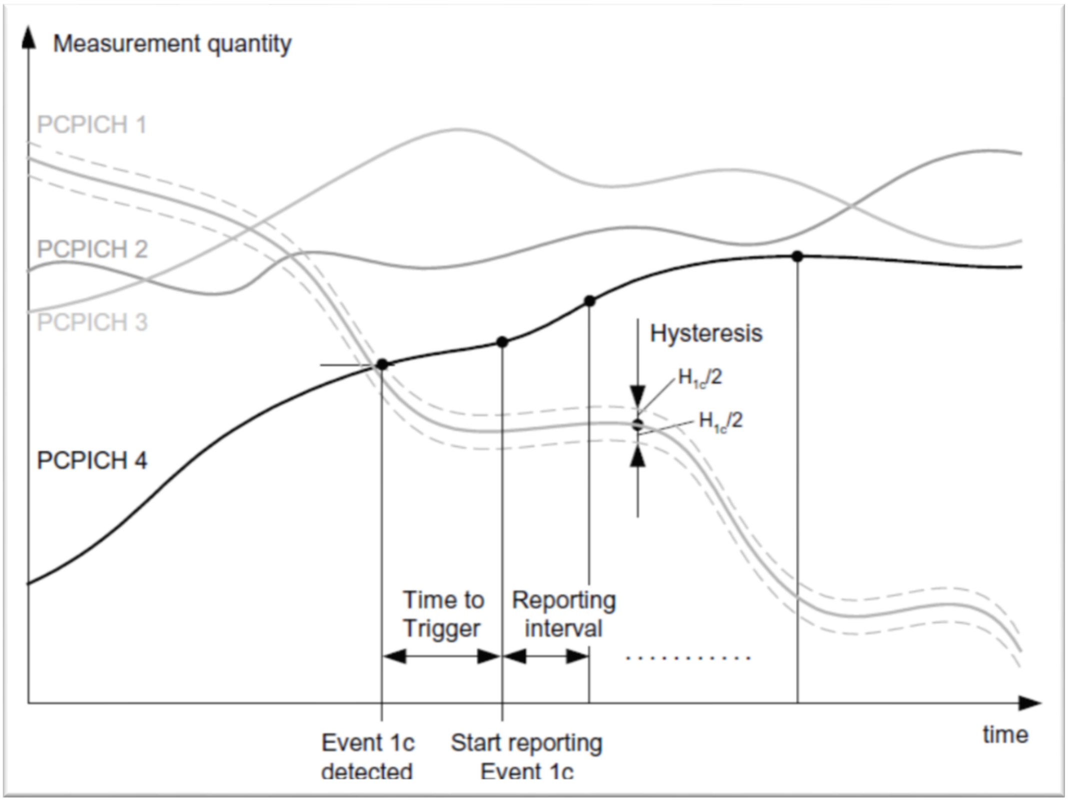

Figure 16. Event 1c, Intra-frequency handover [4]

2.3.3.7 Macro-diversity

The macro-diversity of UMTS is provided by allowing UEs to be connected to more than one Node B simultaneously. The number of cells that a UE can connect to at the same time is called *Active Set Size*. *Active Set Size* is generally set to three which is default for this parameter. The cells that are in *Reporting Range* (see Figure 15) are sorted descending and UE connects to the first three cells. The cells that are in *Reporting Range* but not in *Active Set* are called *polluter cells.*

UMTS uses Maximal Ratio Combining (MRC) which is the optimum combiner for independent AWGN channels and in which received signals are weighted in direct proportion with regarding to RSSI level. The following formula represents the combiner method:

$$R = \sum_{k=1}^{K} \beta_k r_k e^{j\theta_k} \tag{2.21}$$

Where R is the received power by the user, K is the number of transmitters, α_k is the combining ratio between 0 and 1 where $\sum_{k=1}^{K} \beta_k = 1,\ r_k$ is the received signal from k^{th} transmitter and θ_k is the phase of corresponding signal.

Macrodiversity function is one of the most important functions subject to the proposed thesis. The algorithm explained in this thesis is based on SINR value which is the ratio of Pilot power of connected cells to that of not connected but measured cells and noise.

2.3.4 Frequency Spectrum

The frequency spectrum of UMTS has four separated ranges as illustrated in Figure 17;

1900 Mhz to 1920 MHz ➔ TDD

1920 MHz to 1980 MHz ➔ FDD Uplink

2010 MHz to 2025 MHz ➔ TDD

2110 MHz to 2170 MHz ➔ FDD Downlink

In TDD there are totally 7 channels each has 5 MHz bandwidth and used by uplink and downlink together using different time slots. Subscribers are connected to at least one time slot for both uplink and downlink. The time slots can be shared by 15 users simultaneously. In contrast, Frequency Division Duplex (FDD) uses separate frequency pairs for uplink and downlink each having 5 MHz bandwidth. In FDD mode, WCDMA technology is used which is explained in section 2.3.5 in detail.

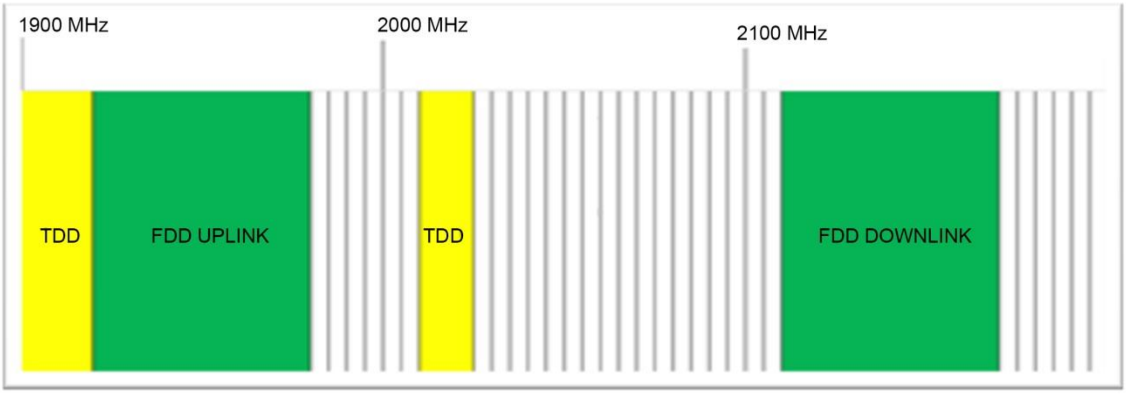

Figure 17. Frequency Spectrum of UMTS in Europe

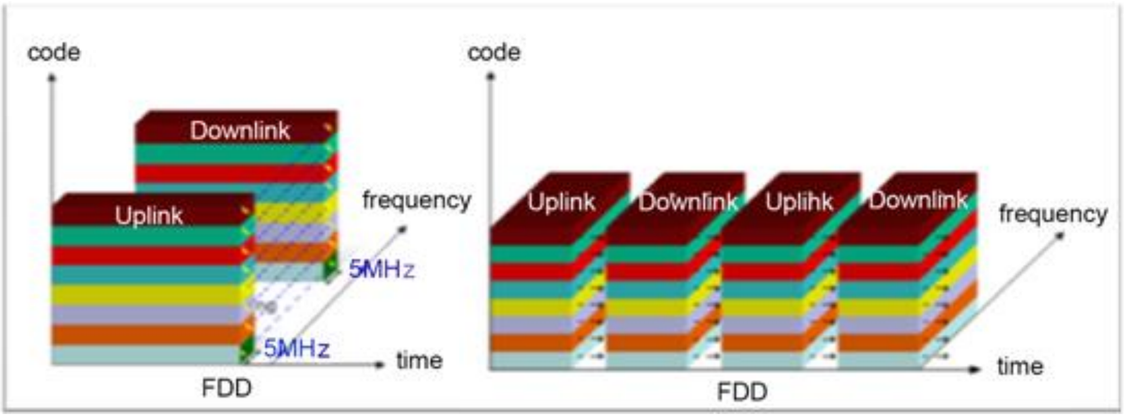

Figure 18. FDD and TDD CDMA [3]

2.3.5 Wideband Code Division Multiple Access (WCDMA) in UMTS

Before mentioning about WCDMA, it is necessary to understand about spread spectrum signals. For a spread spectrum signal, the bandwidth is larger than the information rate required. That is, the bandwidth is expanded by a factor of bandwidth divided by information rate. This rate should be large enough to cope with high interference levels. In spread spectrum signals, since the same bandwidth is used by all users at the same time, a coding scheme is used as an important element in network design, called pseudo-randomness, making the signals appear like random noise and hard to demodulate by other receivers apart from intended ones.

This type of communication technique, using the spreading and coding together, is called Code Division Multiple Access (CDMA).

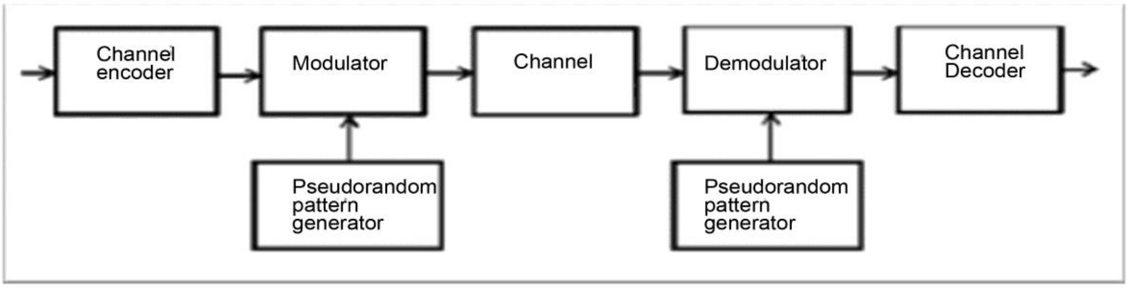

Figure 19. Model of spread spectrum digital communication system [2]

In CDMA, same frequency band is shared by a number of users at the same time. Distinction between users is provided by codes. Namely, a transmitted data can be only understood by the user having the code.

The baseband signal denoted as $v(t)$ is expressed as

$$v(t) = \sum_{n=-\infty}^{\infty} a_n g(t - nT_b) \tag{2.22}$$

where $\{a_n = \pm 1, -\infty < n < \infty\}$ and $g(t)$ is a rectangular pulse of duration T_b. $v(t)$ is multiplied by the code $c(t)$ generated by Pseudorandom pattern generator.

$$c(t) = \sum_{n=-\infty}^{\infty} c_n p(t - nT_c) \tag{2.23}$$

where c_n represents the pseudorandom code and $p(t)$ is a rectangular pulse of duration T_c. The multiplication of $c(t)$ and $v(t)$ is shown in Figure 20. This multiplication spreads $v(t)$ to the wider bandwidth as illustrated in Figure 21 [17].

On the DL, the first thing needed is to separate cells because user equipment is required to know which cell it is connected to. This is done by using Primary Scrambling Codes (PSCs). PSCs do not ensure spreading. PSCs are 512 number of orthogonal codes the rate of which are the same with the corresponding transmitted data rate. Spreading is achieved by Orthogonal Variable Spreading Factor (OVSF). Two main characteristics of OVSFs are orthogonality and the orthogonality is not affected by code length. OVSF codes ensure that different users using the same PSC, namely connected to same cell do not interfere with each other. Since the codes are orthogonal for each user a received signal decoded by another OVSF will be 0. So the intra-cell interference will be almost 0. Using OVSF makes it possible to transmit different data rates at the same time since the orthogonality is not related with code length.

While using OVSF codes, it should be considered that when a small spreading factor is chosen, the number of users that the Node B can serve reduces. To illustrate, in Figure 22, when $C_{4,1}$ is used, the codes under its branches and the codes on the path to the root of it cannot be used i.e. $C_{8,1}$, $C_{8,2}$… because even though $C_{8,1}$ and $C_{8,2}$ are orthogonal $C_{4,1}$ and $C_{8,1}$ or $C_{8,2}$ are not orthogonal. But still other SF8 codes or the codes having higher spreading factor can be used.

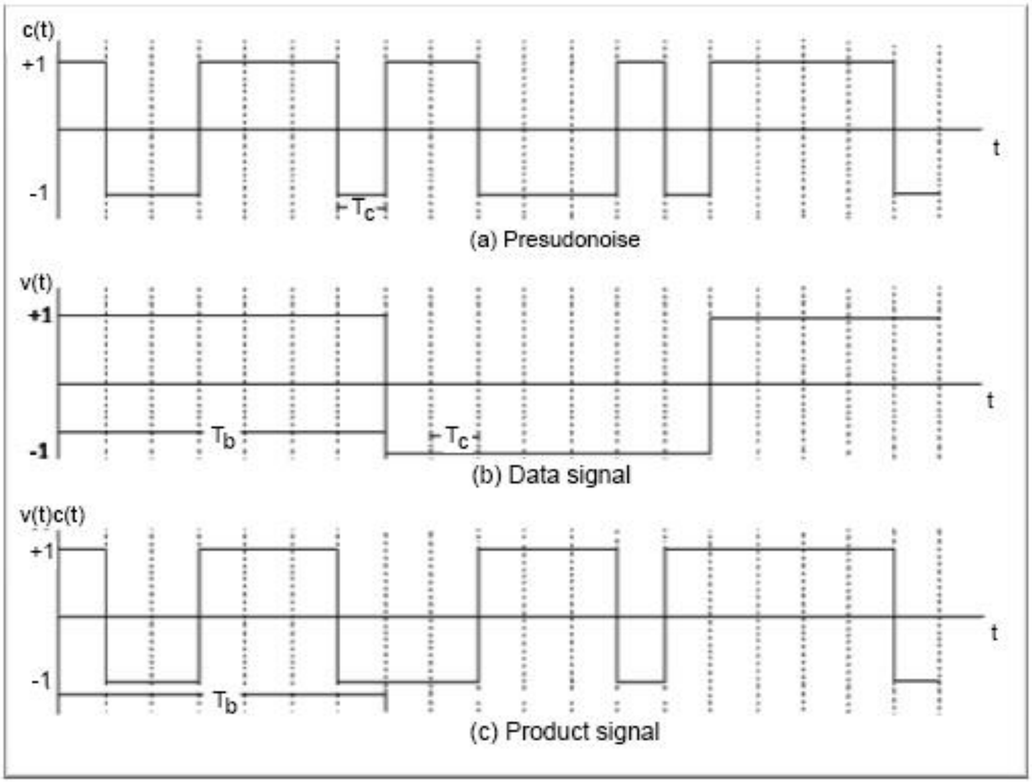

Figure 20. CDMA Example [17]

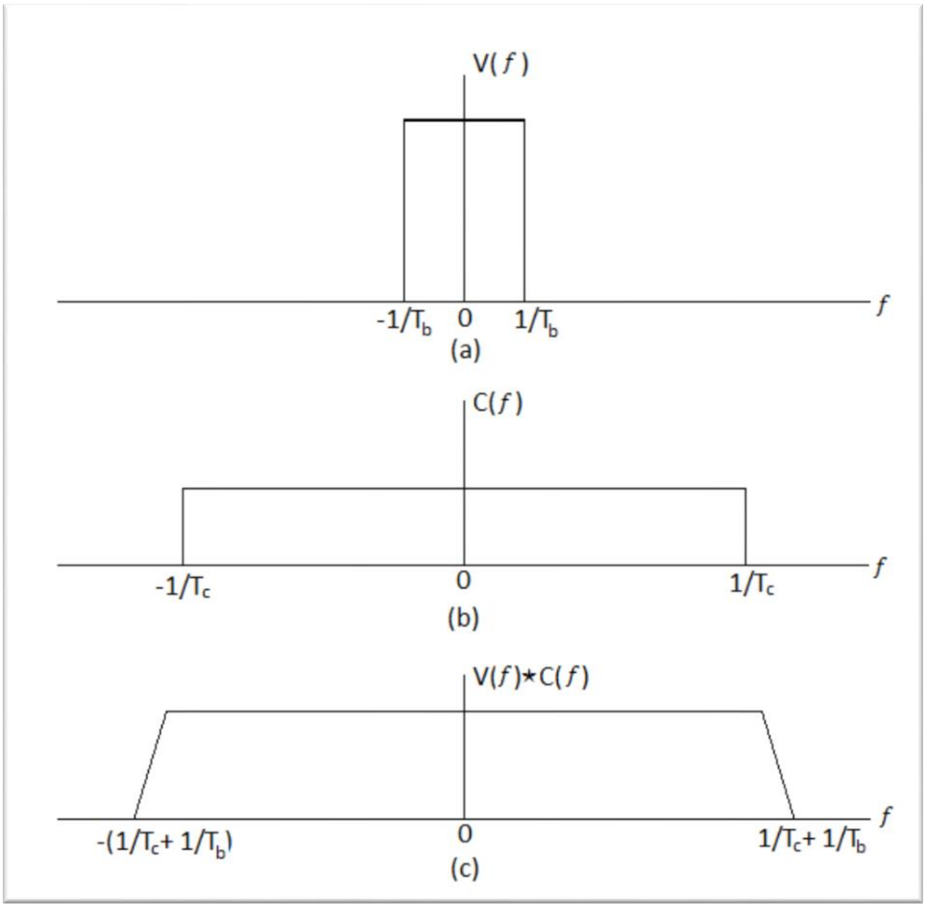

Figure 21. Convolution of spectra of the (a) data signal with the (b) pseudonoise code [17]

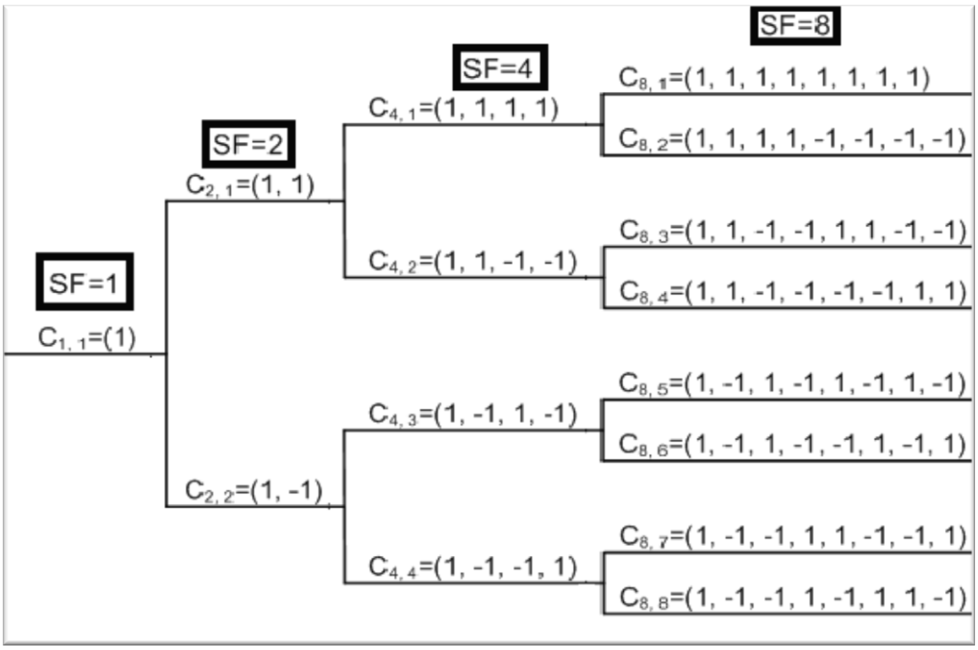

Figure 22. OVSF codes from SF=1 to SF=8

CHAPTER 3

PLANNING AND OPTIMIZATION FOR UMTS RADIO NETWORKS

3.1 Introduction

Planning and Optimization is the most important part for a wireless network to minimize cost while providing high quality of service. A wireless network that planned according to macro information will ensure macro targets mostly. Therefore, it is crucial to consider. However, it is also of the essence to carry out continuous optimization to assure grade of service quality over micro targets. Thus planning and optimization together are to be given weight for a sustainable high quality of service.

Before mentioning to RF planning and Optimization in UMTS, it is necessary to be introduced to deployment process of a UMTS Network. As for all wireless networks, a life cycle as shown in Figure 23 should be carried out: Planning, deployment, initial optimization, and continuous optimization.

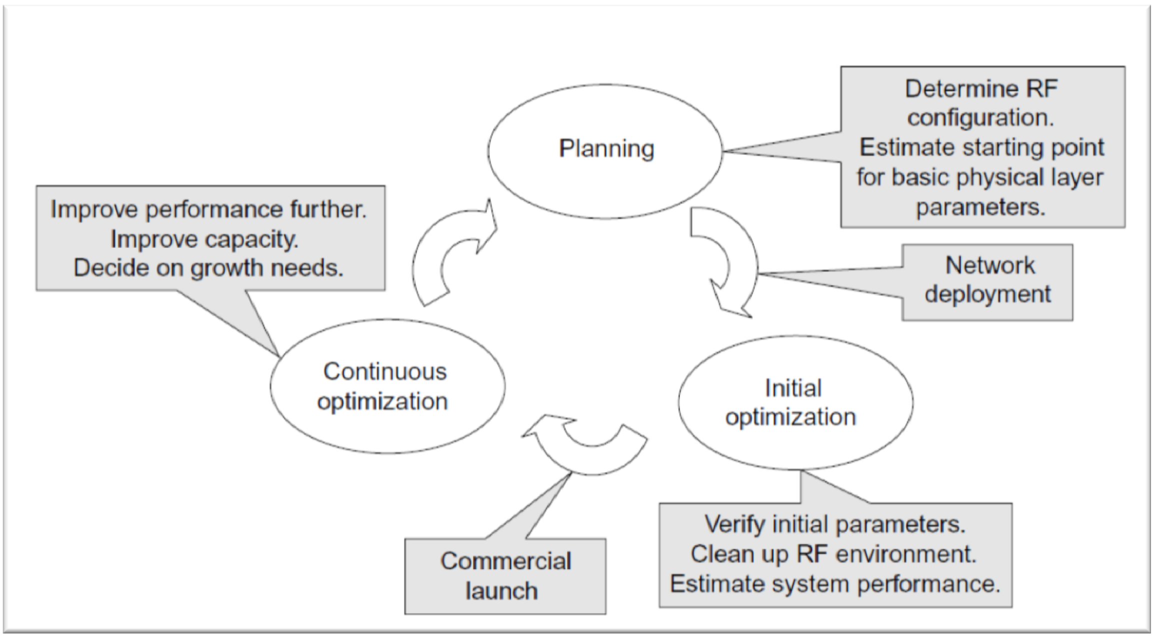

Figure 23. Network life cycle [4]

3.2 Planning

There are two steps in planning; nominal design and detailed plan.

Nominal design includes the decision of the number of sites needed to the target area in order to ensure coverage and capacity using link budgets and RF models by using WCDMA planning tools.

During the detailed plan, the position, azimuth, tilt and transmit power of the sites are decided by using planning tools and giving required information. However, during the first deployment process of UMTS base stations, GSM BTS locations are to be used to avoid extra cost. WCDMA planning process can be summarized as in Figure 24.

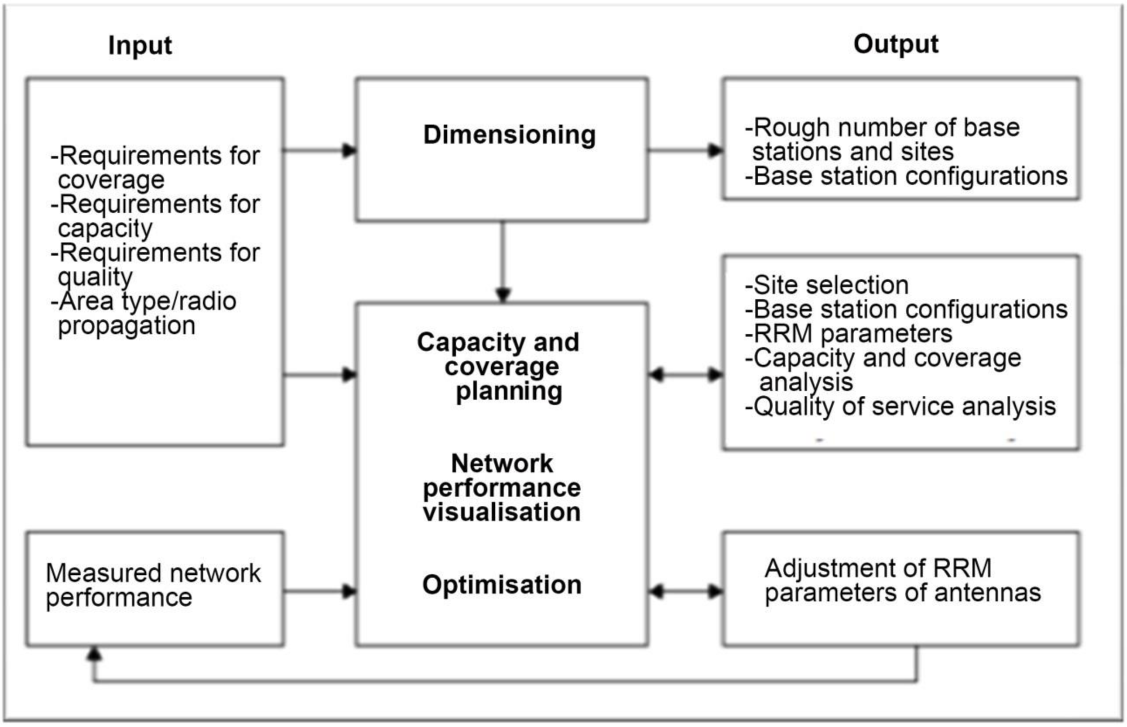

Figure 24. WCDMA planning process [1]

Dimensioning is the process during which estimations are carried out about the network configuration and amount of network equipment based on coverage, capacity and quality of service. This process covers also link budget calculations, base station hardware selections, RNC specifications, and CN elements.

Link budget parameters used in WCDMA planning that makes direct effect on site coverage are interference margin, fast fading margin and soft handover gain.

Interference margin is used during planning since it affects capacity of the cell. If a cell is planned to take high load, it should be given large interference margin, and the coverage area should be narrowed to avoid interference. A 3dB interference margin allows 50% more traffic allowed on the cell.

Fast fading margin is needed for slow-moving mobile users to avoid unnecessary handover because of instant temporary fading. Typically 2-5 dB is used for this parameter.

Soft handovers give gain thanks to macro diversity against slow fading and fast fading. This gain is generally assumed 2-3 dB during planning including both slow and fast fading.

3.3 Initial Parameter Settings

Parameters have important roles on network behavior by providing flexibility to configure the system. In UMTS Networks, parameter configurations are kept in RNCs and CNs and controlled via Operation and Maintain Centers.

Parameters are categorized under the following titles; physical layer parameters, intra-frequency cell reselection parameters, access parameters, intra-frequency handover parameters [4].

3.3.1 Physical Layer Parameters

Physical Layer Parameters control frequency management and selection. Frequencies are defined by UTRA Absolute Radio Frequency Channel Number (UARFCN). The relation between frequency and UARFCN is shown in the following formula.

$$Frequency = UARFCN * 200\ kHz \tag{3.1}$$

where 200 kHz is the channel raster and UARFCN is the number of channels broadcasted on common channels to UEs. Adjacent channel interference can be minimized by using UARFCN.

PSC planning is another subject to physical layer parameters. PSCs are used to differentiate cells on downlink. Therefore, it is vital to care about that on PSC planning the cells using the same PSCs should not overlap in coverage and must be as far as possible from each other.

Power allocation is also controlled by physical layer parameters. To avoid power wasting, common and dedicated channel coverage areas should be comparable.

3.3.2 Intra-frequency Cell Reselection Parameters

UEs, in idle mode, keep its connection quality by monitoring other cells and reselecting the one that satisfy the condition required to apply cell reselection. The conditions are mainly based on hysterias between connected and monitored cells. Hysteria can be defined as a relation parameter between two cells that makes one of the cells attractive or unattractive compared to other one for the processes such as handover or cell reselection. Hysterias are also effective on overlapping coverage borders avoiding pin-pon between cells resulting in a number of unnecessary handovers in which it is more possible to experience drops.

To avoid unnecessary signaling, another method is hierarchical structure. It is based on the speed of mobiles. A fast-moving mobile is not connecting micro cells which are deployed for slow-moving mobile. Thus, unnecessary reselection signaling is avoided.

3.3.3 Access Parameters

The importance of access parameter is due to the effect on latency. During call origination, termination, and other processes such as Location Area, Routing Area or cell update, access parameters are used including any signaling. Using downlink path loss, and uplink interference information, initial power of the connection is calculated by using access parameters. Thus, incorrect planned access parameters may result in too long connection time.

3.3.4 Intra-frequency Handover Parameters

These parameters are used to control handover from one cell to another using the same frequency avoiding unsuccessful attempts. RNC periodically controls Measurement Reports sent by UEs. With regard to handover parameters assisted by these reports, handover is decided. This may be, intra-frequency, inter-frequency, and inter-system handover. If intra-frequency measurements are fulfilling the necessary conditions, first choice is intra-frequency handover.

One of the Intra-frequency handover parameter is set as threshold for measurement meaning that only for the cells satisfying this condition, measurement report is created. Other parameters related with that are cell offset and hysteria between connected and reported cells increasing and decreasing the threshold to enter measurement interval.

3.4 Initial Optimization

After the deployment, initial optimization process starts with RF configuration including, antenna type, azimuth, tilt, and height so as to reach aimed measured signal (Received Signal Code Power) and interference E_c/I_0 level. During this process primary scrambling code assignments and monitored cell list parameters can be optimized. Other parameters should be optimized during service optimization.

Target RSCP should be taken as -70 dBm ± 10 dBm and stationary as possible. This level is on the interval that a UE can detect from -25 to -107 dBm. Interference calculation is done by measured cell list, not detected. That is, only the reported cells are taken into account in which the cells that are reported but not connected by the mobile are taken as interferer.

At this stage the first aim is not RF optimization. The first thing to consider is a reliable call access and retention. Namely, the considerable point is sustainability of the connection rather than the quality of it.

A process so-called site inception is necessary to ensure all configurations and parameters are set and adjusted as planned such as checking the azimuth and tilt of the site.

Site verification is also an important part of this stage. The test for site verification is not a performance test. It is more focused on if functions of each cell are working or not. So a few number of test is enough.

3.5 Continuous Optimization

Once the service requirements are achieved for the deployed network with the initial optimization, continuous optimization begins. It aims to increase network performance especially in a statistical view since it is not possible to log every user. To do this, network counters are logged in every 15 minutes. Based on this counters a number of formulas are applied according to Key Performance Indicators (KPIs). These KPIs are gathered under some titles. Accessibility, Retainability, Mobility, Integrity, and Delay/Latency are common KPI titles. To have brief information;

Accessibility: used to see the performance on CS and PS domain service setup and activation success.

- *Call Setup Success Rate*: the fraction of the successful call attempts to the total number of attempts.
- *PDP Context Activation Success Rate*: the fraction of successful Packet Data Protocol context activation attempt to the total attempt number.
- *SMS/MMS Success Rate*: the fraction of successfully terminated SMS/MMS to the total SMS/MMS attempt.

Retainability: used to see the number of drops in Network.

- Call Drop Rate: The fraction of the number of dropped calls to the total number of calls.
- PDP Context Drop Rate: The fraction of the number of dropped PDP context to the total number of PDP context connections.

Mobility: used to see the performance on users that are moving.

- Soft Handover Success Rate: The fraction of the number of successful soft handovers to the number of total soft handovers.

- Hard Handover Success Rate: The fraction of the number of successful hard handovers to the number of total hard handovers.
- Inter Radio Access Technology (IRAT) Handover Success Rate: The fraction of the number of successful IRAT handovers to the number of total IRAT handovers.

Integrity: used to see the average rate of successful message delivery.

- PS Throughput: the average of successful PS data delivery.

Delay/Latency: used to see the delay on setups or activations.

- Call Setup Delay: the average delay time of successful call setups.
- PDP Context Activation Delay: the average delay time of successful PDP context activations.

Some cases that can be encountered in optimization process are low CPICH power, low E_c/N_0 , primary common pilot channel overshooting, pilot pollution, and missing neighbor.

In low CPICH RSCP case, if RSCP power is lower than threshold value determined for that area on so many measured points, it may be necessary to plan a new site. It is possible to solve this problem by increasing the CPICH power but this time the coverage will increase and network quality will be decreased. Also it is possible to cause interference on other points.

Even though RSCP is high enough, it is possible to have low E_c/N_0 , because of pilot signal from many cells. As mentioned before, a UE can connect 2 or more Node B at the same time and these connected devices are called Active Set. This number is editable but generally set to default and it is 3. So, UEs measures the RF signals and connect the first three cells according to their pilot power. However, being in the first three is not enough to participate in Active Set. The pilot signal level should be also in a predefined range according to best server. Therefore, the pilot signals that are measured but not in Active Set causes pilot pollution. Then to different case can be encountered in pilot pollution. When the Active Set size is lower than maximum possible, it may be chosen to put 3^{rd} cell in Active Set by increasing pilot power, giving up tilt or adjusting azimuth. If Active Set size is at maximum then the polluters should be given down tilt or pilot power should be decreased for polluters.

Another case frequently encountered is overshooting. This is the case that a cell is measured far away from its location that is not in the planned coverage area. Then a down tilt will probably solve the problem. It is also essential to ensure the azimuth in some cases.

Missing neighbor case appears when neighbor list of a Node B is not well defined. This directly affects mobility KPIs since a mobile will not handover to the cell that is not defined as a neighbor even though it is the best candidate that it can connect.

3.6 Drive Testing

Drive Testing (DT) is the indispensable part of optimization and planning in UMTS as in other mobile networks. The aim of a DT is to measure the coverage, capacity and Quality of Service of a mobile network in terms of received power, SINR, and events such as cell reselection or handover.

The technique consists of a number of user equipment with special software connected to a computer via USB interfaces. Each user equipment has different tasks such as idle mode, short call, long call, downloading large file or small file. Each task aims different measurements about network. Short call task is to observe Call Setup Success Rate (CSSR), while long call task is to observe the number of dropped calls, handover success rate. The UE used in idle mode aims to observe cell coverage and cell reselection behavior. Small file downloading aims to measure PDP context activation success rate, while large file downloading aims to measure data rate.

DT can be carried out for indoor and outdoor environment. The only difference is that for outdoor environment a motor vehicle is used.

During DT, the measurements and events are pointed on map with the help of a GPS tool connected to the computer.

3.7 Optimization Algorithms for UMTS

Mainly, four main lines of vision are used separately or combined to optimize UMTS Networks. A related work shall be examined which uses combination of these methods.

3.7.1 Traffic Load

These are based on traffic load distribution of cells aiming uniform distribution. By this way, efficient usage of radio resources can be achieved. Parameters to optimize in algorithms based on traffic load of cells are tilt and CPICH power. Cumulative cell based statistics of different time periods are used as input to the algorithms. The idea is to offload traffic of congested cells to uncongested cells by expanding the coverage of uncongested cells while narrowing that of congested cells. The transfer is carried out between neighbor cells whose coverage areas are overlapping.

3.7.2 Self Optimizing Network

This approach uses the advantages of Remote Electrical Tilt (RET) devices which can control antenna tilt without going to sites and parameter management via Operation and Maintenance Center (OMC). The statistics which is gathered with different time periods and/or measurement reports are used as input to the algorithms. In this respect, Self-Optimizing Network (SON) approach is used as an integrant to other approaches. SON approach also provides wireless networks to execute smart reflexes to changes in network. To illustrate in busy hours where traffic load increases a more appropriate configuration can be configured automatically.

3.7.3 Iterative Methods

These type of methods uses rule based iterations or genetic algorithms. Statistics, Measurement Reports or Drive Test results can be used for this type of methods. Iterative methods may reach the network targets after too many steps which is not acceptable in terms of stability of the network and high reconfiguration cost. However, a well-designed algorithm combined with self-optimizing network approach will be useful for all wireless networks.

3.7.4 Location Advising Methods

The aim of these types of algorithms is to find best locations for Node Bs. The locations can be selected either from a number of candidates or any location from the optimization area. These models can take not only statistics, measurement reports or drive tests but also the installation cost for each location into account [27], [28]. These algorithms are used in planning step of network life cycle shown in Figure 23.

3.8 Self-optimization of Antenna Tilt in Mobile Networks

Using Remote Electrical Tilt (RET) Technology provides mobile networks to optimize load sharing by giving up and down tilt to the cell without going to site. Moreover, it is possible to change tilt configurations dynamically during the day with a statistically, automatically and previously decided schedule. The presented algorithm in [15] uses the advantages of RET.

The process starts with identifying Grade of Service (GoS). It is determined based on call drop rate (CDR) and blocked call rate (BCR).

$$CDR = \frac{N_{drop}}{N_{admitted}} \tag{3.2}$$

$$BCR = \frac{N_{block}}{N_{attempt}} \tag{3.3}$$

where N_{drop} is the number of dropped call, $N_{admitted}$ is the total number of calls, N_{block} is the number of blocked calls during attempt, and $N_{attempt}$ is the total number of call attempts. Combining both metrics;

$$GoS = 1 - (BCR + CDR) \tag{3.4}$$

GoS is used as the first indicator on service quality. Secondly, other indicators should be taken into account that will provide the information about the load and resource availability of corresponding cell to understand the reason under low quality. Thus, it will be decided to adjust cell loads using antenna tilt configuration update.

In WCDMA, total power of cells shared by common and traffic channels. The power used by common channels is fixed, but the other part used by traffic channels is not, since it depends on the traffic load on it, and the distance between user and cell. Then, the ratio between power used by traffic channels and total power reserved for traffic channel can be used as an indicator about the cell load.

$$\eta_{DL} = \frac{P_{used}}{P_{total}} \tag{3.5}$$

where P_{used} represents used power and P_{total} represents total available power.

Another indicator is about OVSF code availability. Figure 25 shows an example of code usage.

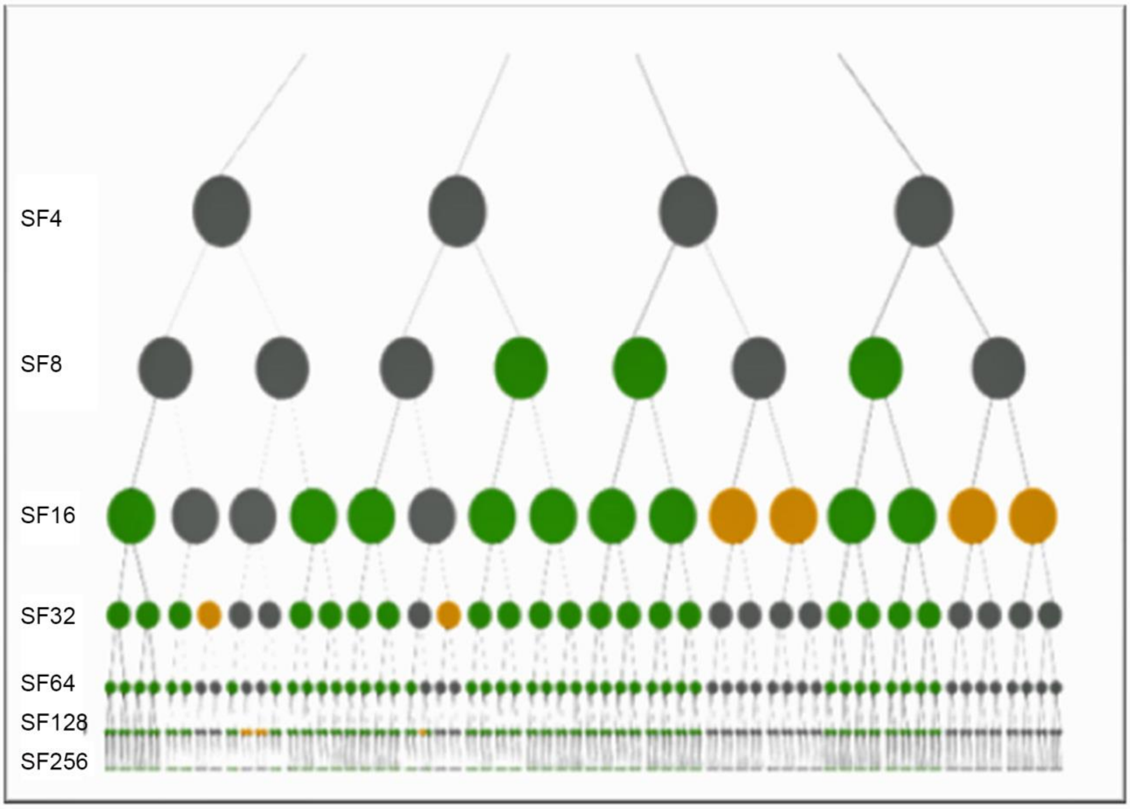

Figure 25. OVSF Code Usage

As mentioned before in this thesis, when a code in this tree is used, another code in its path to its root or in its branches till the end cannot be used due to the loss of orthogonality. In Figure 25, oranges shows used codes, greys are not available and greens are available. Then, remembering common channels, our indicator should be;

$$\eta_{CC} = \frac{N_{used}}{N_{total} - N_{reserved}} \tag{3.6}$$

where N_{used} represents used codes, N_{total} represents total codes, and $N_{reserved}$ represents codes reserved for common channels.

When GoS is under a threshold determined according to network targets for a cell, η_{DL} and η_{CC} are checked if low GoS value is due to cell load or not. If one or both is over threshold, load of corresponding cell is to be offloaded to another uncongested cell using antenna tilt.

Load balancing using tilt is achieved by giving downtilt to congested cell and uptilt to a neighbor uncongested cell whose coverage area is overlapping with congested one. Downtilt and uptilt should be carried out step by step with a predefined step size. At each step the KPIs should be measured again as in Figure 26.

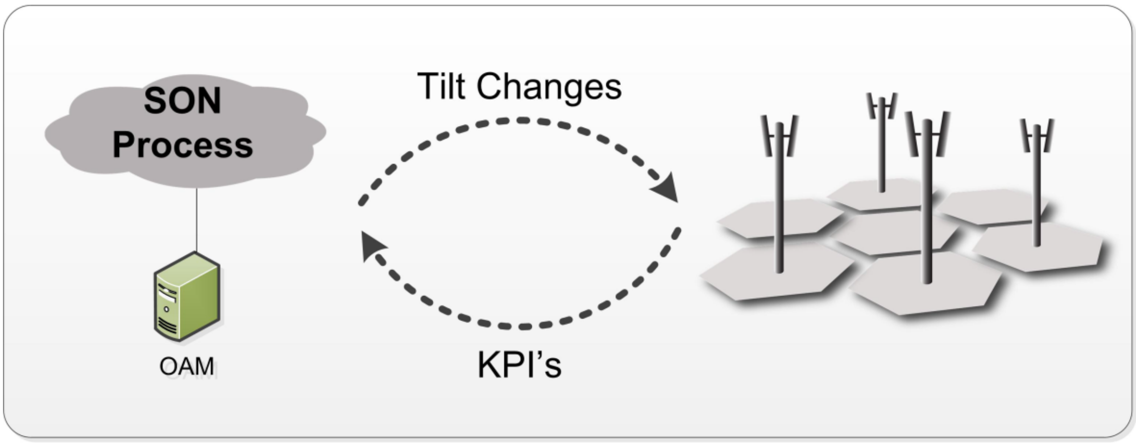

Figure 26. Self-Optimizing Network Process using antenna tilt [15]

When deciding the cell that will be used to offload of congesting cell, Handover success rate from congested to offloading should be high to avoid unsuccessful handovers which will cause user drop.

It is also important that offloading cell should be close as possible to congesting cell. Besides, azimuths of offloading and congesting should look to closer areas that they have overlapping area to avoid outage.

Lastly, while choosing the offloading cell, its available resources should be enough. This can be measured using again η_{CC} and η_{DL}.

Consequently, taking hourly statistics, KPIs, it is possible to get cells that are under thresholds and adjust tilt configuration by down tilting congesting and up tilting its neighboring offloading cells.

The proposed method in [15] presents a practically applicable algorithm with help of a software placed in OMC of UMTS Networks. The algorithm equally distributes the traffic load by using simple equations. However, it should be indicated that RETs are still not widely used. Therefore, the algorithm should be applied only on completely RET used areas. In the following section two scenarios are simulated and the proposed method is applied.

3.9 Simulation Results

Two simulations are carried out to test the algorithm proposed in [15] explained in section 3.8 by using Remcom's Wireless InSite tool. The performance is measured in terms of load distribution, average SINR and number of satisfied users. Wireless InSite is a simulator for wireless communication that uses general ray-tracing method in 3D environment.

Scenario 1

The first simulation is carried out on Dupont Circle, Washington city map provided by the Wireless InSite tool's examples using 6 Node Bs placed each having 3 sector and 364 randomly placed receivers as shown in Figure 27. Initial configurations for the sites are written in Table 4. After applying the algorithm, the adjusted site configuration results are shown in Table 5. The site, sector, antenna, active set and frequency spectrum information of the simulation are shown in Table 6.

In this simulation, the cells that are in Active Set more than 80 measurement points (MPs) are assumed to be congested. According to the assumption three cells are selected as congested and 1 degree downtilt is applied to those cells to narrow the coverage area at each step. Three other cells whose coverage areas are overlapping with congested cells having low load are given uptilt to enlarge their coverage areas.

Table 4. Initial site configurations

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Azimuths (degrees)	0, 90, 180	0, 100, 180	0, 180, 225	0, 270, 320	0, 180, 280	0, 60, 250
Height (meters)	46	51	43	52	55	49
Tilts (degrees)	6, 6, 6	6, 6, 6	6, 6, 6	6, 6, 6	6, 6, 6	6, 6, 6
CPICH Power (dBms)	36,36,36	36,36,36	36,36,36	36,36,36	36,36,36	36,36,36

Table 5. Adjusted tilt configurations after 6th step

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Tilts (degrees)	12, 6, 6	6, 0, 6	6, 6, 12	6, 0, 6	12, 6, 6	6, 0, 6

Table 6. Simulation parameters

Frequency (MHz)	2100
Bandwidth (MHz)	5
Antenna Gain (dBi)	18
Number of sites	6
Number of sectors per site	3
E-plane Half Power Beamwidth (degrees)	6.4
H-plane Half Power Beamwidth (degrees)	64
VSWR (transmitter/receiver)	1.25/1.25
Temperature (K)	293
Receiver antennas	Omni /0 dBi
Active set size	3
Active set window	10 dBm
Noise power (dBm)	-174
Target SINR (dB)	0.5

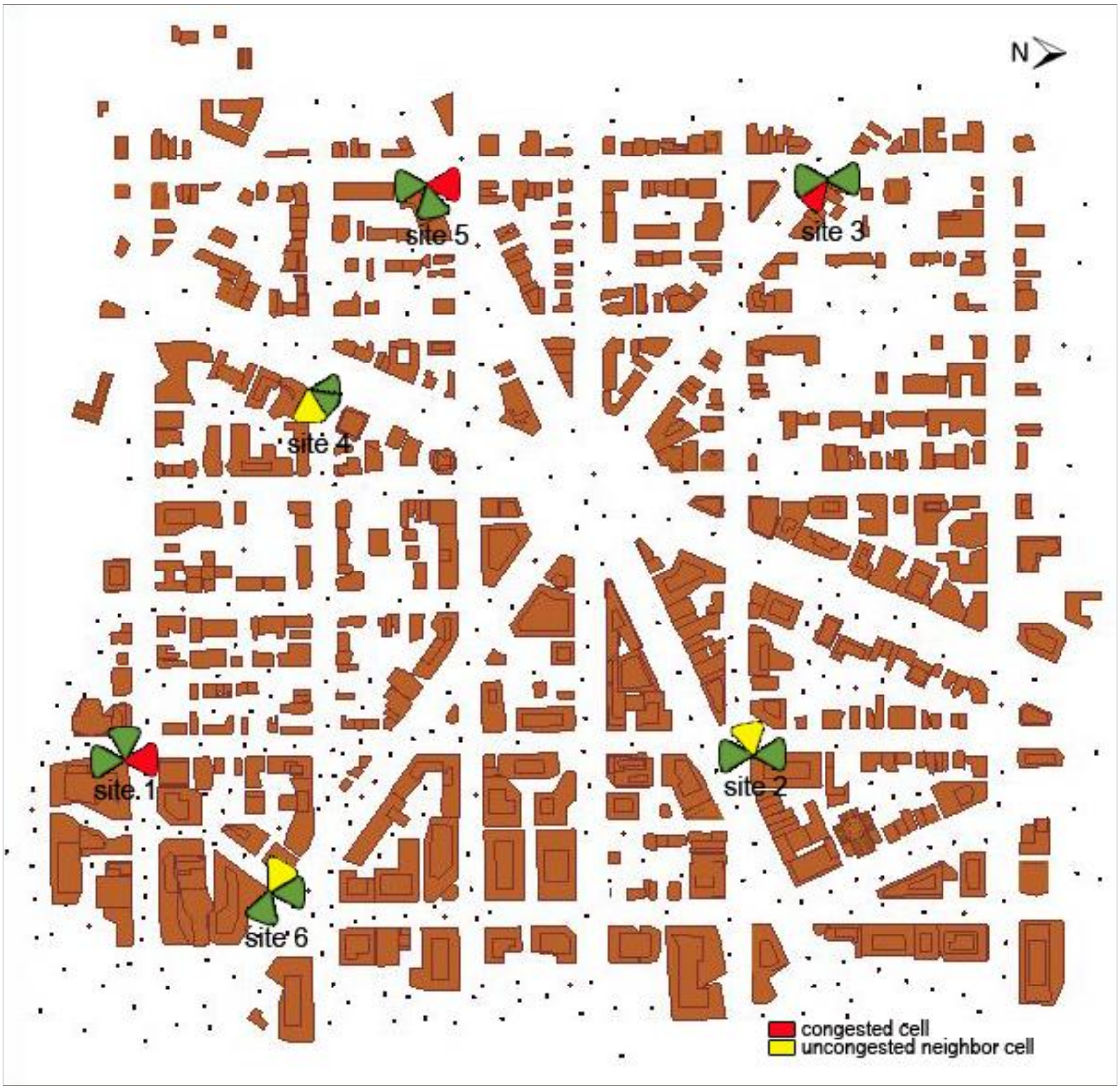

Figure 27. Simulation area

Simulation Results of Scenario 1

The aim of the algorithm proposed in [15] is to share the total traffic load uniformly among the cells. In Figure 28, it is clearly seen that the number of measurement points that congested cells serve are decreasing at each iteration as expected while the total number of served remains almost constant. It means that the algorithm succeeds more uniform distribution proving the effect of antenna tilt adjustment on cell load and resulting in better statistics.

Moreover, it is important to measure the effect on SINR. As can be seen from the Figure 29 and 30, the percentage of measurement points that are under threshold (equal to 0.5 dB) is decreasing and average SINR is increasing.

According to the figures, it is seen that antenna tilt adjustment using cell load information has also positive effect on signal quality. Since the algorithm gives downtilt to congested cells, they serve closer measurement points with higher received power. Thus most of the measurement points getting higher SINR value.

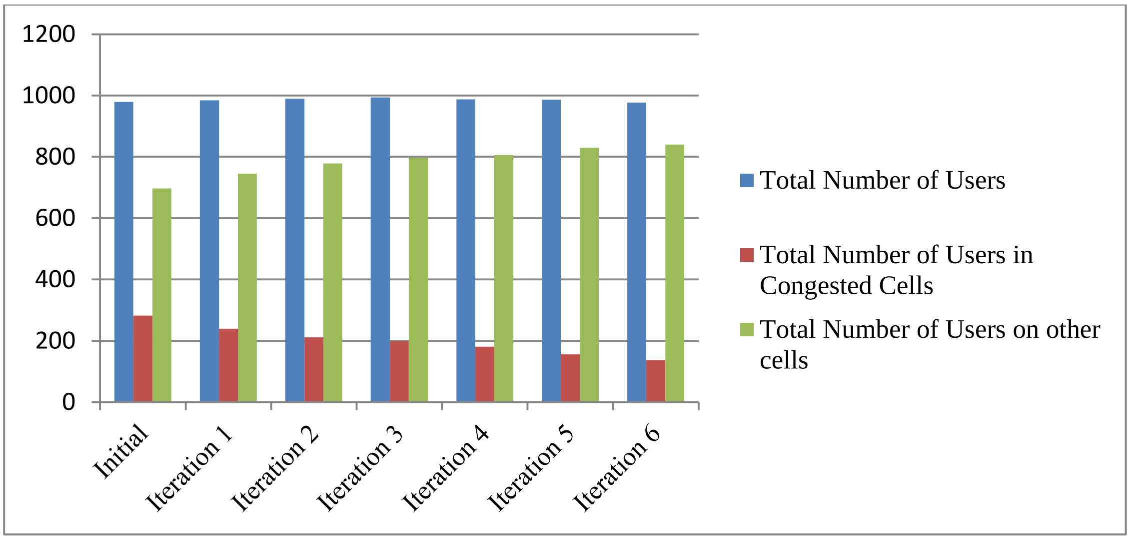

Figure 28. User distribution

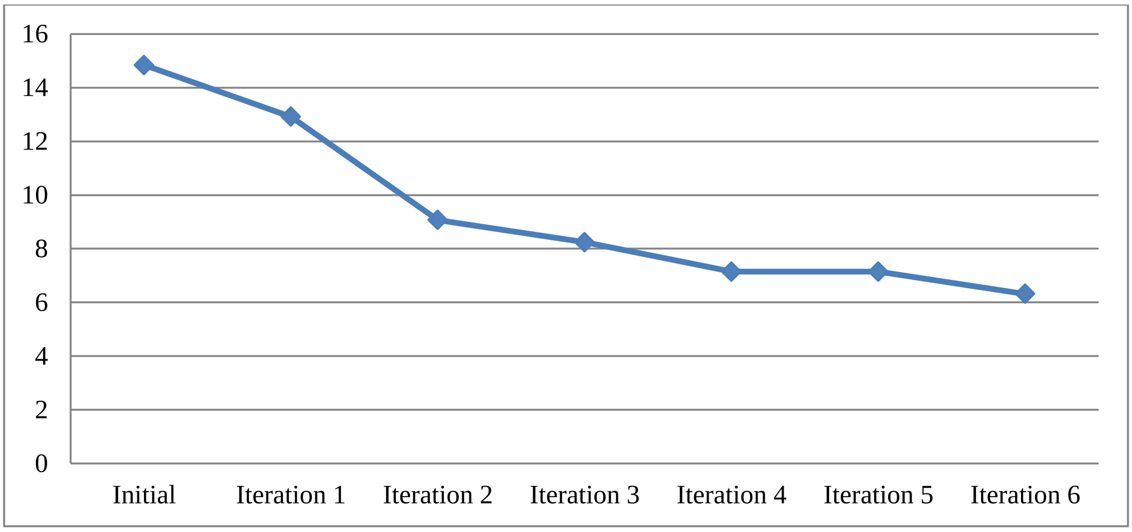

Figure 29. Percentage of MPs under threshold

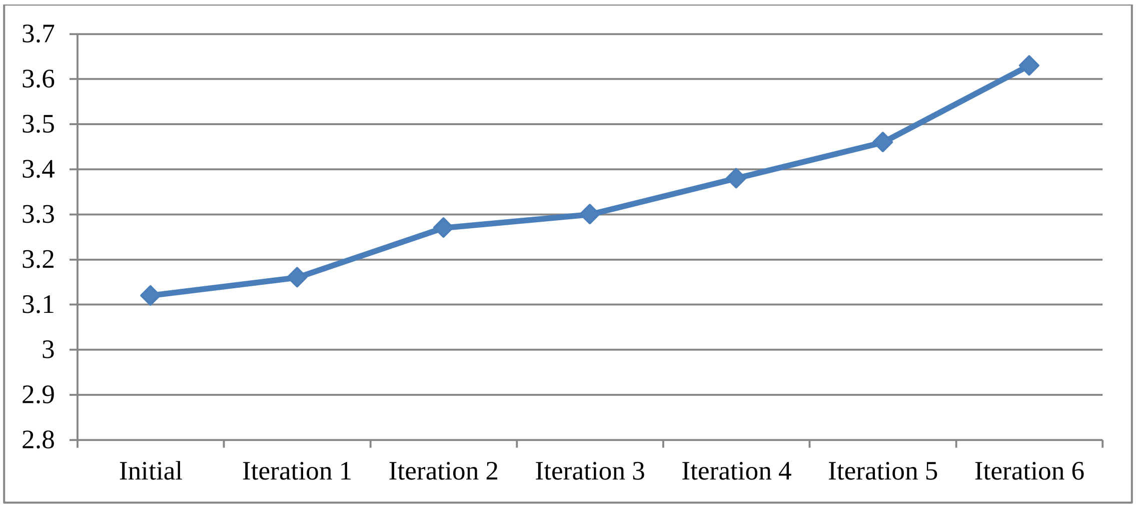

Figure 30. Average SINR

Figure 31. Simulation area

Scenario 2

The second simulation is again carried out on Dupont Circle, Washington city map provided by the Wireless InSite tool's examples using 6 Node Bs placed the same locations using the same configurations as in Scenario 1 stated in Table 4 and 365 randomly placed receivers as shown in Figure 31. The aim of using the same configuration is to compare the algorithm in different traffic distribution. After applying the algorithm, the adjusted site configuration results are shown in Table 7. The site, sector, antenna, active set and frequency spectrum information of the simulation are the same as in scenario 1. The same rule to decide congested cells is applied and four cells are selected to be given downtilt and four other cells whose coverage areas are overlapping with congested cells.

Table 7. Adjusted site configuration after 6th step

	Site 1	**Site 2**	**Site 3**	**Site 4**	**Site 5**	**Site 6**
Tilts (degrees)	12, 6, 6	6, 0, 6	6, 12, 12	12, 6, 6	0, 6, 0	6, 0, 6

Simulation Results of Scenario 2

In Figure 32, it is clearly seen that the number of measurement points that congested cells serve are decreasing at each iteration again as expected while the total remains almost constant. The effects on number of measurement points under threshold and SINR can be seen on Figure 33 and 34.

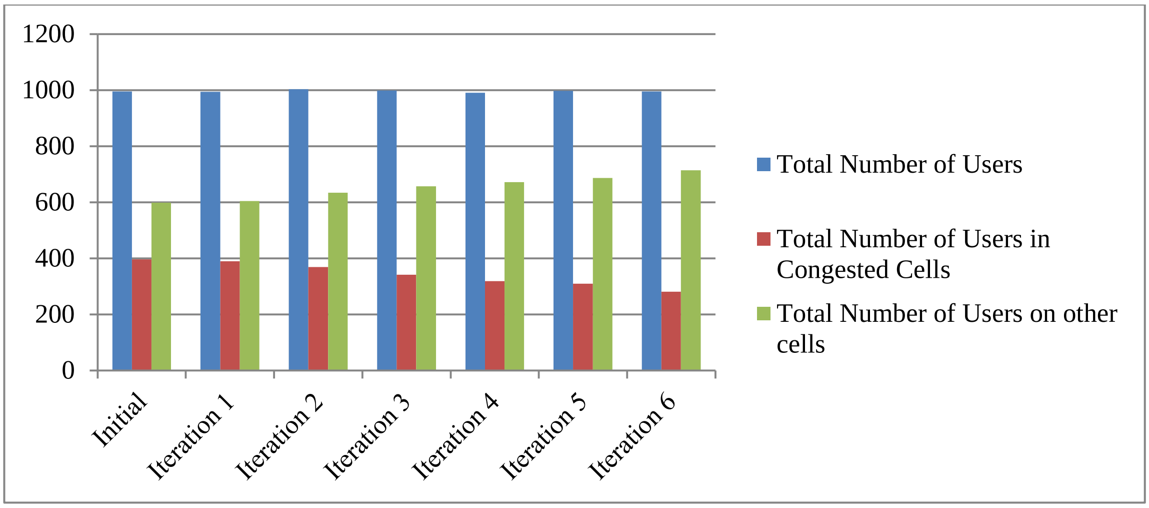

Figure 32. User distribution

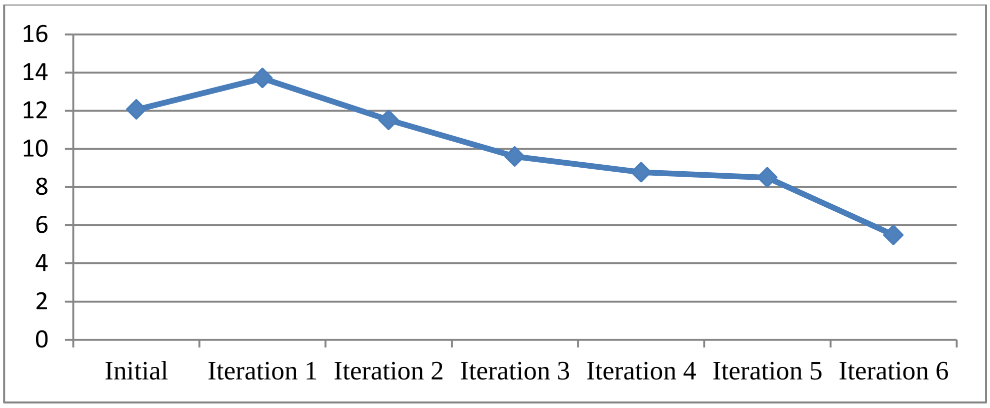

Figure 33. Percentage of MPs under threshold

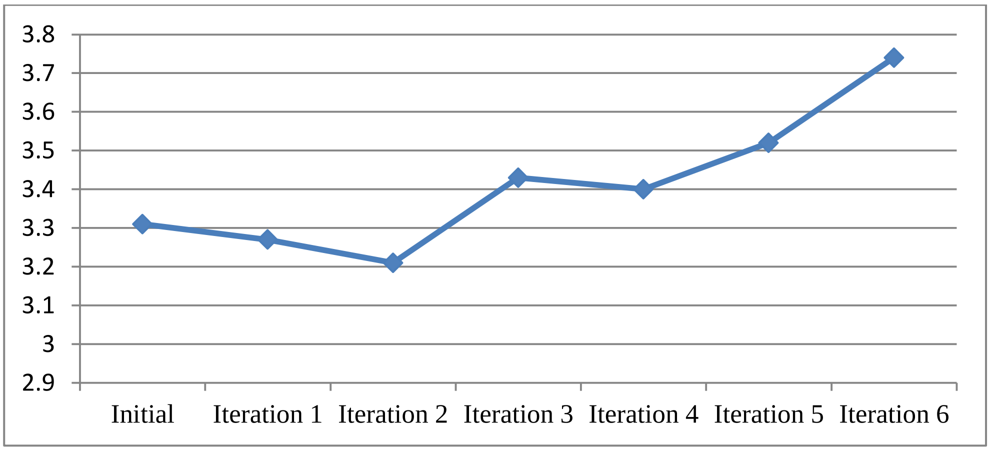

Figure 34. Average SINR

CHAPTER 4

SINR BASED INTERFERENCE MANAGEMENT ALGORITHM FOR UMTS NETWORKS

The purpose of the algorithm explained in this chapter is to adjust antenna tilt, azimuth and CPICH power of UMTS Networks using SINR and received power at receiver side.

The proposed algorithm consists of two steps: first step adjusts tilts and common pilot channel powers, the second step adjusts azimuths.

The first step includes identification of problematic area, calculation of average received powers from the identified problematic area of each cell, identification of interferer cells, calculation of tilts and CPICH powers respectively.

In the second step, a weighted average azimuth for each cell is calculated. The distance and angle of measurement points to the cells are used including all measurement points where corresponding cell is in Active Set. After that this azimuth is combined with initial azimuth of corresponding cell. The underlying motivation of this step is to direct the transmit antennas to the measurement points where the corresponding cell is in active set. However due to the unpredictable behavior of radio wave propagation, the calculated azimuth is not applied directly and combined with initial azimuth. The combination is proportional to the number of measurement points where the corresponding cell is in active set. The more measurement points served, the more the azimuth is turned to the calculated azimuth. All these steps shall be explained in the following sections in detail.

4.1 Identification of Problematic Area

Two different methods are examined. First one is DT measurement technique which is simulated in terms of received power by placing measurement points with 5m intervals on a route as measurement points. Second one is randomly placed measurement points. Received powers are taken for each measurement point as output of the simulator. After that SINR value is calculated for each measurement point.

The algorithm works with parameters given by user of the algorithm as input. One of them is SINR threshold ($SINR_{thre}$) in dBs and another is Implementation Reference Length (IRL) in number. $SINR_{thre}$ indicates the minimum aimed SINR level and IRL is the number of measurement points defining the number of points that will be taken into account before and after whose SINR value is under threshold. In Figure 35, IRL is explained with an example where IRL is equal to 5. These parameters should be determined according to network targets and physical conditions. IRL should be selected smaller for urban areas while larger in rural areas. SINR is checked for each measurement point respectively to the route. When the SINR value is lower than the threshold, a rule is applied according to the average measurements of previous and next measurement points which are in reference area bordered by IRL.

Algorithm 1: SINR Check

** Check SINR level for each Measurement Point and Compare with SINR threshold.*

for *i = 1 to N*

    if $SINR_i < SINR_{thre}$

    then call *Algorithm 2*

end for

where *N* is the number of measurement points in the whole area, $SINR_i$ is the measured SINR level for measurement point i, $SINR_{thre}$ is defined SINR threshold. if $SINR_i$ is lower than $SINR_{thre}$ then the area centered at point i and covering the measurement points bordered by IRL is defined as problematic area. *Algorithm 2* is described in the next section. SINR is calculated by the following formula among the received powers from the cells which are included in reporting range as seen in Figure 35 for reporting range.

$$SINR = \frac{\sum_{i=1}^{AS} R_i}{\sum_{i=AS+1}^{T} R_i + N} \tag{4.1}$$

Where AS is active set size, R_i is the received power from i^{th} cell, T is the number of cells in reporting range for the i^{th} measurement point, and N is the noise power.

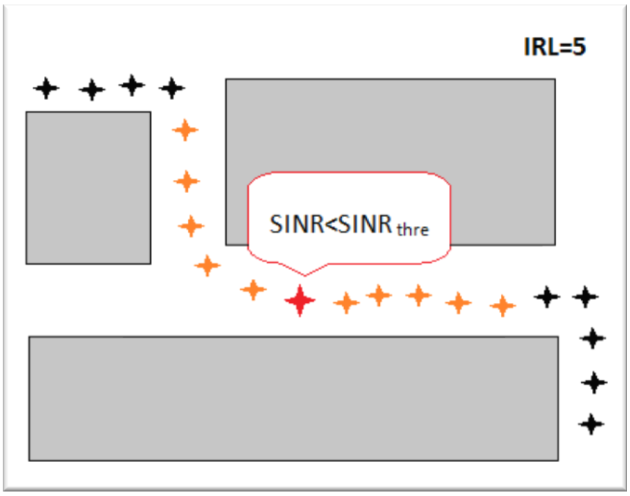

Figure 35. Implementation Reference Length example with $\boldsymbol{IRL}$ = 5, the red points SINR level is under threshold and orange measurement points are to be used as implementation reference including red point too.

4.2 Identification of Interferer Cells

Since problematic area is detected by SINR in Algorithm 1, it is needed to identify interferer cells in that range. To detect the interferer cells, three parameters are taken into account; AS, IRL, and Active Set Window (ASW).

The measured received powers on implementation reference area bordered by IRL is used to separate serving and interferer cells according to average received powers among the measurement points in it.

Active set size is used at two stages; In the first stage, the SINR for all measurement points are calculated. In the second stage, interferer cells are detected. If active set size is 3, 4^{th} and other transmitters in active set window are taken as interferer. Namely, first three cells in terms of received power are serving signals and others are interferer.

However, in proposed algorithm, when a point under threshold is detected, the interferer of that point itself is not accepted as real interferer for that area. Interferer cells are decided according to the average received powers among the implementation reference area. The underlying reason is to serve the measurement points with the cells that are planned to cover them.

After selecting the implementation reference area, arithmetic mean of received powers from all cells are calculated and sorted. First three cells are accepted to cover this area and others that are not in first three but larger than interferer threshold are taken as polluter (or interferer) cells. Interferer threshold is a parametric value set by the user according to the network targets.

In the following algorithm, the process to sort received power averages and detecting interferer cells for the measurement points identified in Algorithm 1 is shown.

Algorithm 2: Identify Interferers

** calculate the total received power from each cell within the implementation reference area length of* $2 * IRL + 1$ *centered at the point identified in Algorithm 1;*

for $i = 1\ to\ M$

  for $j = 1\ to\ 2 * IRL + 1$

    $TRP_i = TRP_i + RP_{ij}$

  end for

end for

** calculate the average received power from each cell within the implementation reference area and sort the average received powers from each cell;*

for $i = 1\ to\ M$

  $ARP_i = TRP_i/(2 * IRL + 1)$

end for

for $i = 1\ to\ M - 1$

  for $j = 1\ to\ M - i$

    if $ARP_j < ARP_{j+1}$

      $temp = ARP_{j+1}$

      $ARP_{j+1} = ARP_j$

      $ARP_j = ARP_{j+1}$

    end if

  end for

end for

** decide if the cell that are not in active set are interferer or not*

for $i = (AS + 1)\ to\ M$

  if $ARP_i > ARP_{thre}$

  then *interferer*$[i] = 1$ * i^{th} *cell is interferer*

end for

where M is the total number of cells, RP_{ij} is the received power by j^{th} measurement point from i^{th} cell, TRP_i is the total received power from i^{th} cell within the implementation reference area, ARP_i is the average received power from i^{th} cell, ARP_{thre} is the threshold value in dBm that an interferer should be reduced till under this level.

4.3 Interference Cancelation

Interference cancellation is done by down tilt and reducing CPICH power if needed. To decide how many degrees down tilt is required to cancel interference, a parameter is essential which indicates the received power reduction on measurement point when the interferer cell is 1 degree down tilted. This is, of course, depends on the physical conditions of paths from the corresponding cell to user equipment. However, a statistical arithmetic mean can be used.

There are two constraints on reducing interference. First one is the maximum allowed downtilt. It changes according to antenna model. Therefore, the maximum antenna tilt is defined as a cell based parameter that can be different for each cell in the algorithm. Second one is minimum CPICH power allowed which takes effect when maximum down tilt is not enough to cancel interference, CPICH power is reduced. Therefore it is needed to calculate an average value that the effect of 1 degree down tilt on measurement points in terms of received power.

The following formulas are applied to calculate the new tilt value of an interferer cell. The following formulas compares the required tilt $P_{ave_i} - P_{thre}/TE$ with the available tilt range equal to $MT_i - IT_i$ where P_{ave_i} is the average received signal from the corresponding cell on implementation area, P_{thre} is the threshold for interferer, IT_i is the initial tilt of the corresponding cell, MT_i is the maximum allowed tilt for the corresponding cell, and TE is the average effect of 1 degree down tilt on measurement point.

In case of where required tilt is equal to or smaller than available tilt range the reviewed tilt for i^{th} cell, RT_i, is calculated by the following formula;

$$RT_i = IT_i + \left(\frac{P_{ave_i} - P_{thre}}{TE}\right) \tag{4.2}$$

When required tilt is larger than the available tilt range, then RT_i is set to MT_i for the corresponding cell and CPICH power is set to the predefined value $CPICH_{reviewed}$ which is to be smaller than current.

Moreover, it is also significant to point out that one cell can be found as interferer for more than one time in the implementation area. Then the maximum tilt calculated among them is applied to that cell.

The flow chart for tilt and power adjusting algorithm is shown in Figure 36 including Algorithm 1 and 2. First, all measurement points are checked. If the SINR is under threshold for a measurement point, the point with its neighborhood is considered as problematic area and received powers on that area sorted for all measurement point separately. After that all interferers are checked if they are under interferer threshold or not. If an interferer is over threshold, required antenna down tilt should be calculated and applied. When required antenna down tilt is not possible due to the maximum down tilt, CPICH power of the corresponding cell is reduced.

A DT measurement example is shown in Table 8. Measurement point 289 is under threshold value and to be optimized. Active set window (or reporting range) is set to 10 dBm and the implementation reference length is set to 15 in this execution of the algorithm. In Table 8, the red colored cells on the last line are defined as interferer cells and the received powers taken from these cells inside the implementation area are to be reduced by the rule explained in this section.

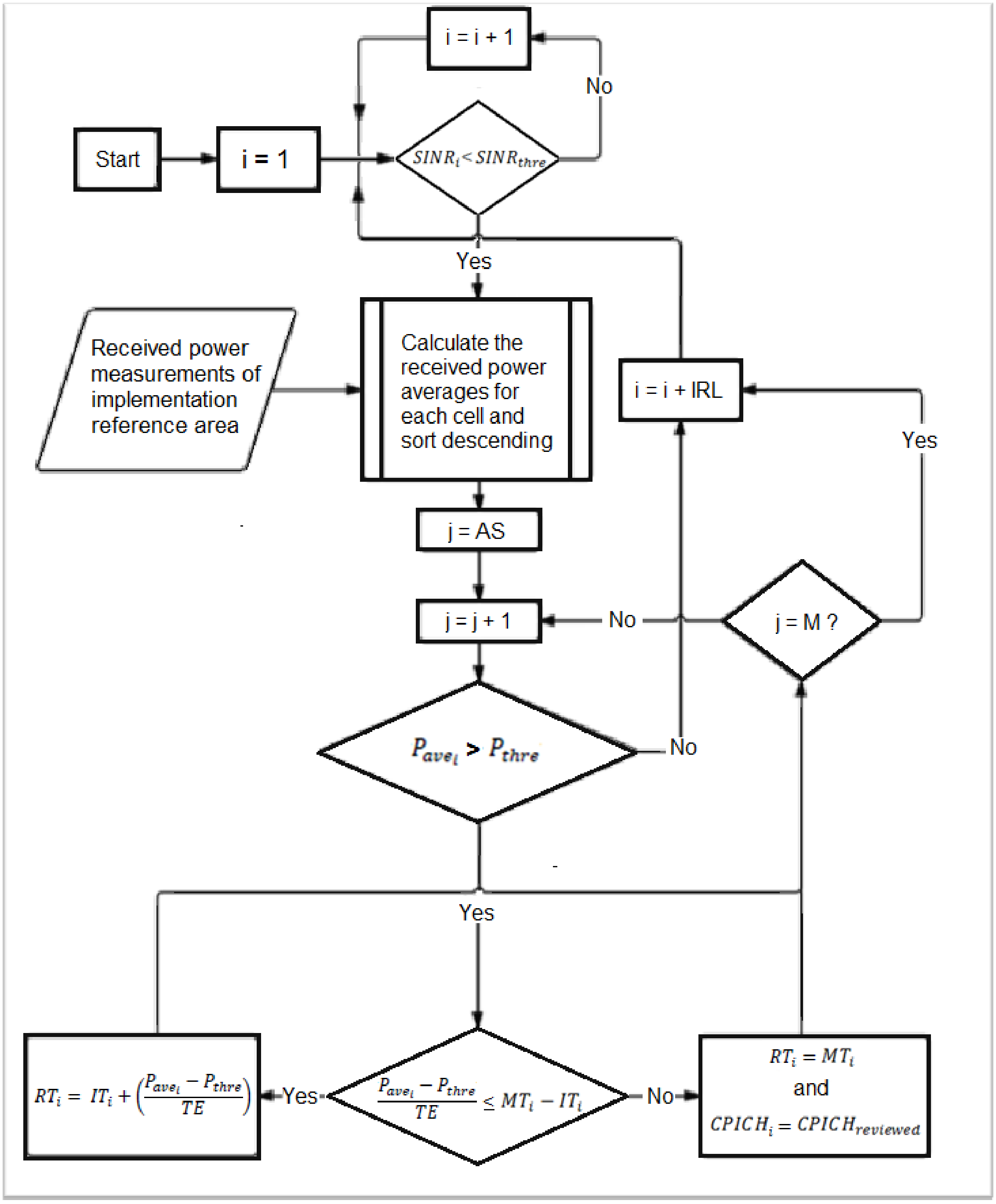

Figure 36. Tilt and CPICH power adjusting flow chart

Table 8. A measurement example from simulation where dark green shows the best serving cell, light green indicates the cells in active set, red represents interferer cells over threshold and MP means Measurement point

	Cell_11	Cell_12	Cell_13	Cell_21	Cell_22	Cell_23	Cell_31	Cell_32	Cell_33	Cell_41	Cell_42	Cell_43	Cell_51	Cell_52	Cell_53	Cell_61	Cell_62	Cell_63	Noise	SINR
MP_274	-97,74	-66,73	-99,33	-110,8	-52,88	-77,19	-39,42	-41,6	-50,11	-59,75	-81,94	-62,57	-45,37	-64,98	-43,08	-62,8	-53,87	-67,56	-174	0,9037
MP_275	-92,78	-64,8	-98,43	-107,2	-57,29	-75,62	-39,2	-44,7	-48,56	-61,2	-81,89	-58,4	-41,11	-69,29	-42,1	-64,56	-62,96	-67,47	-174	0,7343
MP_276	-87,82	-65,08	-98,63	-111,8	-57,16	-73,46	-36,81	-42,78	-39,9	-59,38	-81,85	-62,08	-44,34	-65,89	-41,13	-66,33	-65,72	-81,77	-174	0,6367
MP_277	-75,16	-64,37	-98,59	-116,4	-58,67	-72,05	-36,42	-47,5	-38,35	-58,19	-84,42	-65,28	-46,64	-62,9	-66,03	-56,16	-54,98	-81,79	-174	7,2732
MP_278	-72,45	-60,02	-97,23	-106,3	-60,17	-73,15	-36,28	-50,13	-40,93	-63,03	-86,98	-63,73	-44,94	-61,57	-67,48	-53,32	-51,49	-81,03	-174	7,2419
MP_279	-87,93	-62,08	-97,16	-103,2	-50,95	-74,26	-37,38	-52,14	-61,18	-60,89	-83,57	-62,18	-44,51	-65,93	-68,66	-61,63	-55,91	-67,46	-174	7,0389
MP_280	-86,12	-61,42	-96,99	-100,1	-49,56	-70,78	-38,62	-53,27	-63,71	-61,74	-85,2	-75,8	-45,83	-66,27	-60,18	-58,04	-54,06	-63,54	-174	6,9136
MP_281	-82,95	-60,89	-96,9	-92,24	-47,19	-72,16	-38,74	-54,4	-63,97	-75,28	-78,53	-75,19	-44,45	-62,65	-59,36	-53,93	-50,82	-66,32	-174	6,9757
MP_282	-85,67	-59,62	-95,43	-87,18	-40,7	-68,38	-45,5	-54,3	-64,23	-74,24	-80,66	-69,07	-47,64	-68,52	-63,49	-59,76	-57,94	-69,1	-174	6,8157
MP_283	-87,65	-59,48	-95,43	-77,51	-35,01	-60,69	-43,82	-56,98	-66,08	-57,61	-84,71	-65,06	-47,27	-66,76	-58,65	-63,62	-59,73	-66,54	-174	7,2527
MP_284	-79,99	-58,03	-93,6	-76,7	-35,19	-64,59	-42,39	-54,88	-61,21	-54,11	-84,32	-63,06	-46,91	-71,17	-60,74	-61,64	-60,93	-63,54	-174	7,2567
MP_285	-81,57	-57,95	-93,53	-77,66	-37,94	-72,43	-44,72	-63,82	-51,13	-44,61	-93,28	-51,01	-43,75	-71,87	-65,44	-54,2	-52,01	-61,02	-174	0,8476
MP_286	-78,63	-56,64	-89,78	-80,47	-46,91	-74,58	-45,43	-61,51	-53,05	-45,48	-92,54	-51,67	-40,6	-73,7	-64,57	-54,38	-53,44	-61,66	-174	0,8495
MP_287	-77,92	-56,7	-89,73	-85,62	-43,85	-76,72	-41,7	-63,31	-54,45	-44,03	-86,34	-50,57	-37,18	-70,14	-63,69	-58,49	-56,26	-60,72	-174	0,8805
MP_288	-70,72	-46,9	-81,46	-81,26	-40,79	-71,33	-43,34	-65,1	-55,86	-45,18	-78,86	-50,63	-36,45	-66,18	-49,96	-57,74	-56,58	-80,95	-174	1,0697
MP_289	-71,9	-47,02	-81,53	-84,96	-41,35	-75,44	-42,17	-67,24	-54,22	-40,48	-75,79	-45,62	-40,26	-63,46	-53,89	-59,13	-56,01	-81,51	-174	0,3767
MP_290	-70,99	-46,53	-81,18	-86,55	-43,39	-75,43	-44,35	-69,39	-60,14	-37,9	-72,37	-43,85	-40,76	-63,41	-54,28	-56,95	-53,65	-82,47	-174	0,4646
MP_291	-71,37	-46,65	-81,28	-98,08	-48,13	-75,43	-44,57	-62,32	-55,45	-45,95	-73,42	-50,26	-41,26	-69,71	-55,09	-55,89	-52,63	-83,48	-174	0,464
MP_292	-71,09	-46,7	-81,44	-94,89	-45,24	-66,71	-44,48	-55,26	-51,33	-46,53	-74,48	-49,54	-37,25	-65,32	-59,09	-55,69	-52,06	-84,26	-174	0,7651
MP_293	-70,9	-47,38	-81,59	-91,11	-35,61	-64,88	-47,94	-55,39	-49,64	-44,28	-83,28	-50,58	-35,93	-74,47	-72,74	-55,49	-51,49	-85,04	-174	7,4539
MP_294	-82,93	-56,55	-88,33	-87,33	-39,6	-64,22	-50,39	-57,73	-53,99	-49,78	-88	-52,69	-34,61	-70,28	-69,21	-58,33	-46,72	-85,82	-174	7,3586
MP_295	-81,32	-56,76	-88,64	-83,08	-38,31	-66,4	-51,84	-60,07	-58,33	-48,99	-86,69	-56,02	-36,36	-70,75	-64,91	-61,17	-56,24	-86,62	-174	7,2784
MP_296	-81,31	-57,25	-89	-90,02	-41,05	-67,15	-50,37	-62,11	-66,14	-48,2	-85,38	-53,79	-33,16	-72,81	-71,86	-56,99	-53,52	-87,21	-174	7,4494
MP_297	-80,86	-57,49	-86,85	-94,55	-43,79	-61,15	-49,82	-60,27	-67,32	-47,53	-91,49	-58,59	-33,94	-69,65	-72,38	-57,41	-53,94	-88,42	-174	7,3488
MP_298	-95,17	-74,3	-95,14	-91,36	-44,6	-62,79	-49,27	-58,42	-61,31	-46,87	-95,91	-55,02	-33,42	-74,65	-72,91	-57,84	-54,37	-89,13	-174	7,358
MP_299	-96,25	-74,77	-95,18	-96,22	-45,42	-60,15	-50,58	-54,15	-52,38	-54,59	-89,32	-66,01	-35,35	-71	-76,19	-60,17	-55,81	-90,03	-174	7,165
MP_300	-92,72	-74,5	-95,23	-89,14	-36,85	-63,9	-49,11	-50,44	-49,64	-55,62	-89,27	-66,23	-31,72	-73,75	-79,48	-64,7	-60,98	-90,98	-174	7,6442
MP_301	-101	-74,88	-95,27	-93,78	-36,48	-62,75	-49,54	-53,25	-60,02	-62,28	-89,21	-66,44	-36,19	-77,89	-76,05	-64,93	-61,22	-91,99	-174	7,3678
MP_302	-99,89	-74,86	-95,3	-90,7	-49,84	-69,8	-51,55	-56,06	-55,76	-62,45	-99,04	-69,6	-28,54	-80,1	-69,98	-64,46	-61	-93,07	-174	7,846
MP_303	-96,3	-74,73	-95,34	-87,62	-50,65	-72,56	-49,39	-56,46	-60,66	-53,06	-97,39	-63,32	-27,65	-82,31	-67,5	-63,98	-60,79	-250	-174	7,935
MP_304	-97,15	-74,76	-95,38	-90,36	-50,51	-73,19	-48,24	-56,86	-65,55	-53,23	-98,2	-62,34	-35,68	-79,94	-69,07	-64,97	-61,88	-250	-174	7,132
Avarage	-84,07	-60,83	-91,9	-92,39	-45,33	-69,66	-44,63	-56,19	-55,95	-53,63	-85,62	-59,23	-39,32	-69,91	-63,2	-59,51	-56,1	-89,05	-174	4,9709

4.4 Azimuth Adjustment

Azimuth adjusting is based on the coverage areas of the cells and applied after the results of interference cancelation are taken. Because, applying the interference cancelation algorithm, the coverage for the cells may change. Therefore, the Azimuth adjustment algorithm is applied according to the received power measurement results of interference cancelation as second step. Azimuth adjustment algorithm directs the cells to the measurement points that they are in active set on with weighted average with respect to distance from cell to measurement point and number of points that they are in active set. The underlying reason of weighting to the distance is to direct the antenna's main lobe direction to the measurement points that are farther. Thus, the transmitted power shall be distributed to the measurement points as fair as possible. The following formula calculates the azimuth based on the angle and distance of the measurement point to the cell. This azimuth will not be implemented directly because of the fact that in some cases, the number of points that corresponding cell in active set may not be enough. Therefore the azimuth to be applied shall be calculated as a weighted average of initial and calculated angles.

$$A_{cal} = \frac{1}{D_{total}} \sum_{i=1}^{K} A_i . D_i \quad (4.3)$$

where A_{cal} is the calculated azimuth, K is the total number of points that the corresponding cell is in active set, A_i is the angle of i^{th} measurement point that the corresponding cell is in active set, and D_i is the distance of the point to the corresponding cell as in Figure 37.

D_{total} and A_{app} are calculated as following:

$$D_{total} = \sum_{i=1}^{K} D_i \quad (4.4)$$

$$A_{app} = \frac{A_{call} . K + A_{init} . (N - K)}{N} \quad (4.5)$$

where A_{init} is the initial angle of the corresponding cell, and N is the total number of measurement points.

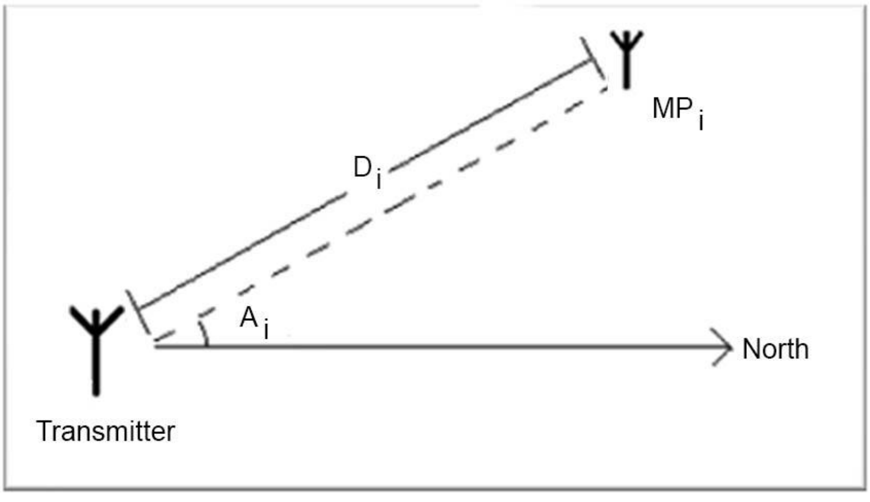

Figure 37. presentation of $\boldsymbol{D_i}$ and $\boldsymbol{A_i}$ where $\boldsymbol{MP_i}$ is the $\boldsymbol{i^{th}}$ measurement point

4.5 Simulation Results

Four simulations are carried out to test the algorithm by using Remcom's Wireless InSite tool.

Scenario 1

The first simulation is carried out on Dupont Circle, Washington city map provided by the Wireless InSite tool's examples using 6 Node Bs each having 3 sector and 1887 receivers placed with 5 meter intervals as shown in Figure 38. Initial configurations for the sites are written in Table 9. After applying the algorithm, the adjusted site configuration results are shown in Table 10. The site, sector, antenna, active set and frequency spectrum information of the simulation are shown in Table 11.

Table 9. Initial site configurations

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Azimuths (degrees)	0, 90, 180	0, 100, 180	0, 180, 225	0, 270, 320	0, 180, 280	0, 60, 250
Height (meters)	46	51	43	52	55	49
Tilts (degrees)	6, 6, 6	6, 6, 6	6, 6, 6	6, 6, 6	6, 6, 6	6, 6, 6
CPICH Power (dBms)	36,36,36	36,36,36	36,36,36	36,36,36	36,36,36	36,36,36

Table 10. Adjusted site configuration

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Azimuths (degrees)	4.5, 83.5, 180	1.5, 94, 168.5	1, 143.5, 166	0, 243.5, 281.5	355.5, 178, 256.5	3, 56.5, 244
Tilts (degrees)	10, 10, 6	6, 11, 11	12, 12, 10	11, 10, 12	11, 6, 12	12, 12, 10
CPICH Power (dBms)	36, 36, 36	36, 36, 36	36, 36, 36	36, 36, 33	36, 36, 33	36, 33, 36

Table 11. Simulation parameters

Frequency (MHz)	2100
Bandwidth (MHz)	5
Antenna Gain (dBi)	18
Number of sites	6
Number of sectors per site	3
E-plane Half Power Beamwidth (degrees)	6.4
H-plane Half Power Beamwidth (degrees)	64
VSWR (transmitter/receiver)	1.25/1.25
Temperature (K)	293
Receiver antennas	Omni /0 dBi
Active set size	3
Active set window	10 dBm
Noise power (dBm)	-174
Target SINR (dB)	0.5
IRL	15

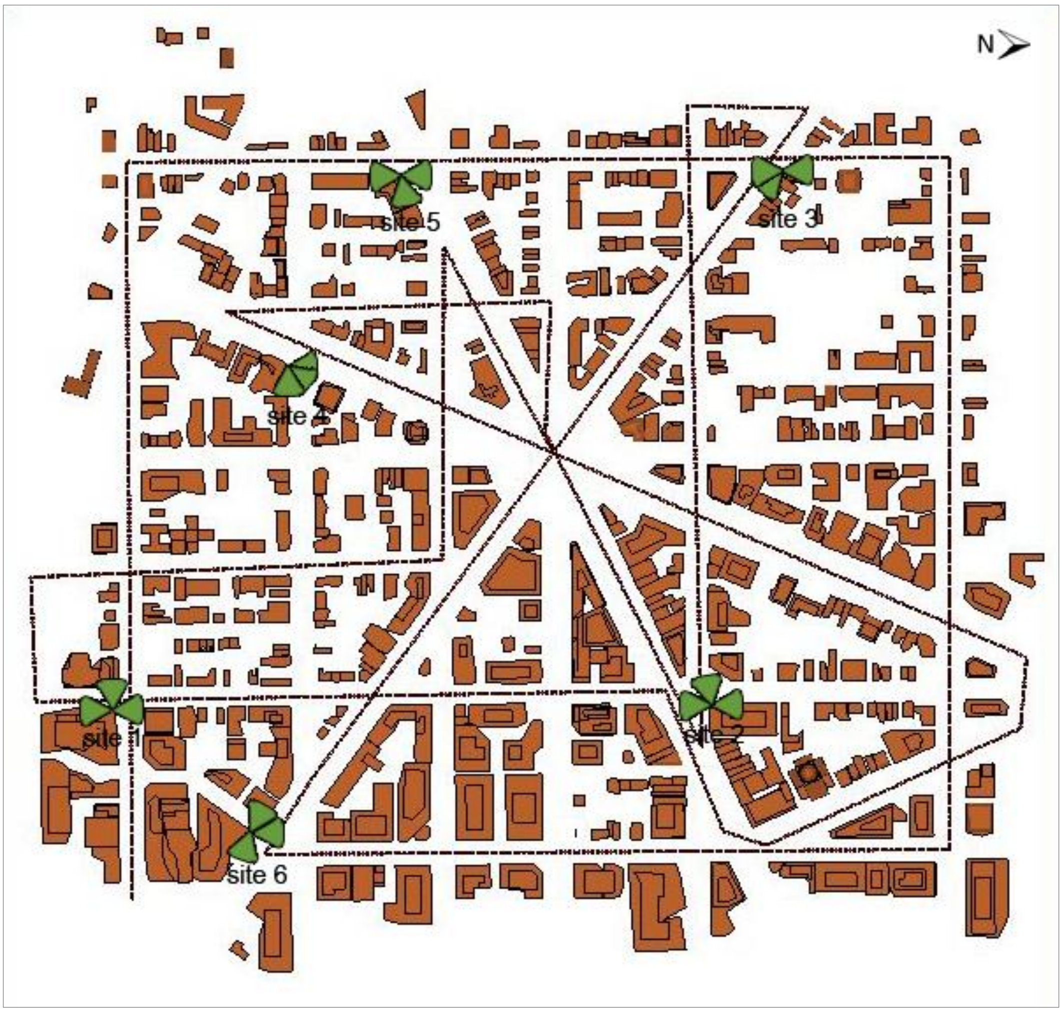

Figure 38. Simulation area

Simulation Results of Scenario 1

As can be seen from the Figure 39 and 40, average SINR is equal to 4.446 and the number of measurement points under threshold is 146 before the adjustments are applied. After the configuration given by Interference Cancellation algorithm is applied average SINR is increased to 4.808 dB and the number of measurement points under threshold is decreased to 126. After that, Azimuth Adjustment algorithm is applied. Average SINR is increased to 5.204 dB and the number of measurement points under threshold is decreased to 95. Another point to emphasize is that total transmitted power reduced 9 dBm. Further, the average number of interferer cells on measurement points is decreased from 0.85 to 0,508 referring 40% reduction.

The SINR value on measurement points before and after adjustment is shown in Figure 41 and in Figure 42 respectively. Best server signal levels before and after adjustment is shown in Figure 43 and Figure 44 respectively.

Figure 41 to 44 clearly show the increase in signal quality visually on map view. These figures show us another improvement on service quality: the distribution of the power is more uniform. This will automatically balance load sharing of the cells. In Figure 45, Cumulative Distribution Function (CDF) of SINR before and after adjustment is given.

As another scheme, to verify the results, 3080 receivers are placed to the study area as XY grid with 20 meter intervals and simulated with initial and adjusted configuration expressed in Table 9 and 10 again. In Figure 46, Cumulative Distribution Function (CDF) of SINR before and after adjustment on XY grid is given. The SINR results before and after adjustments are shown in Figure 47 and 48 respectively. This time overall gain with regard to SINR is 8%.

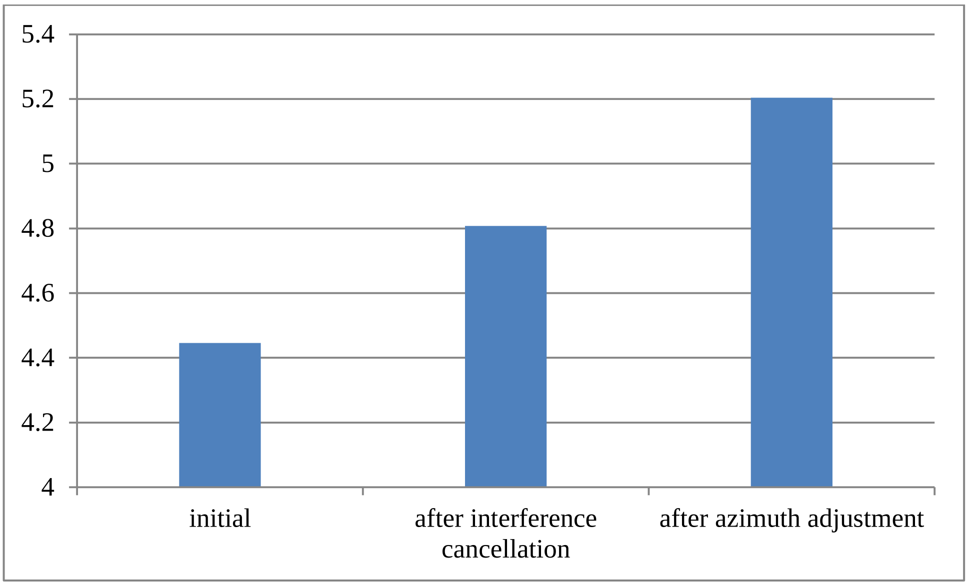

Figure 39. Average SINR

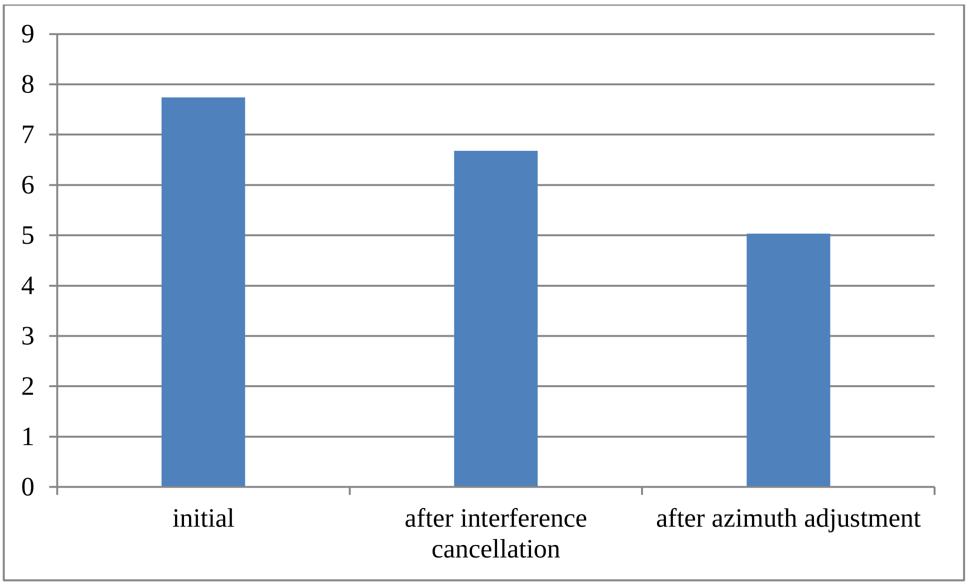

Figure 40. Percentage of MPs under threshold

Figure 41. SINR values before adjustment

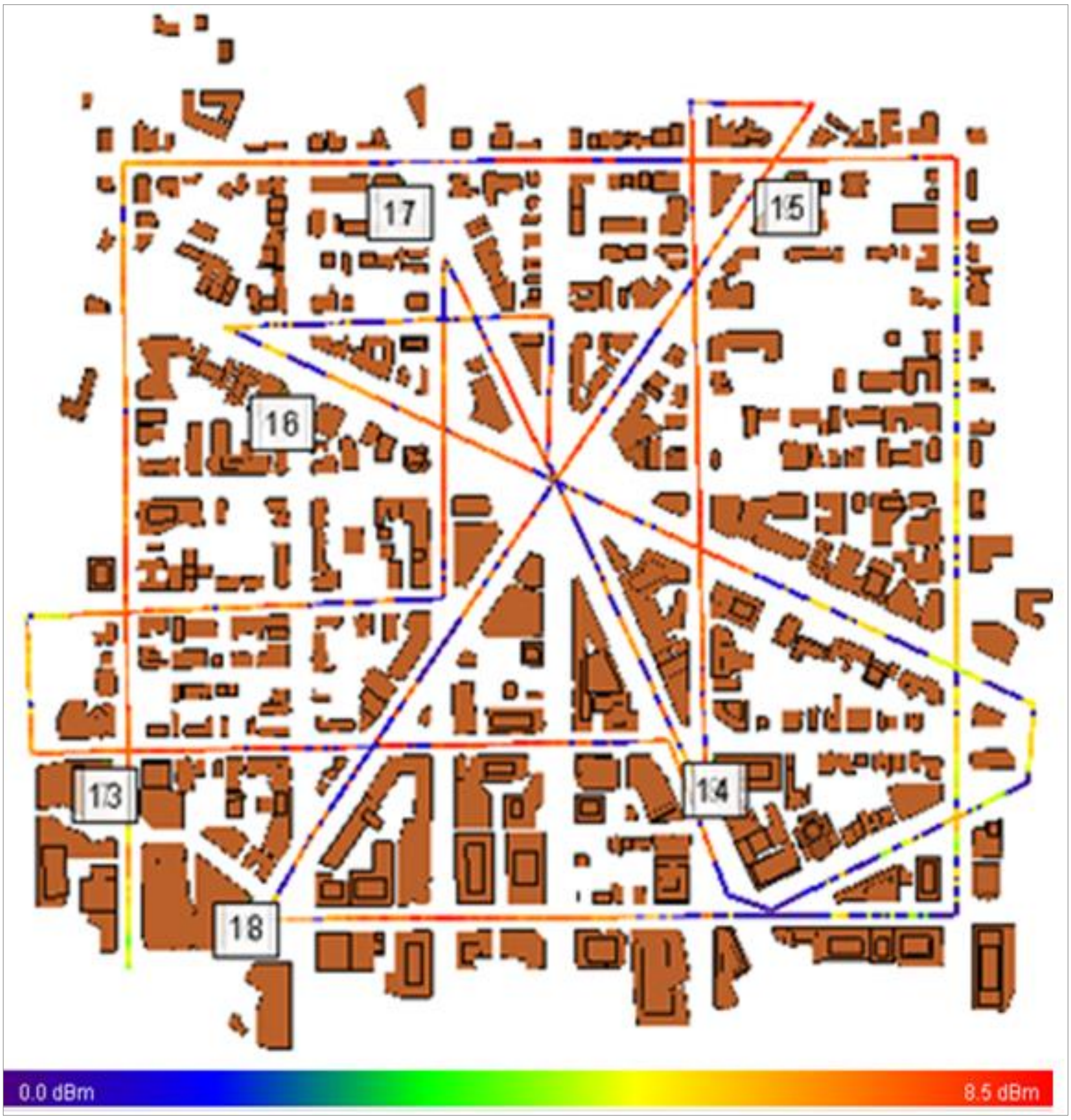

Figure 42. SINR values after adjustment

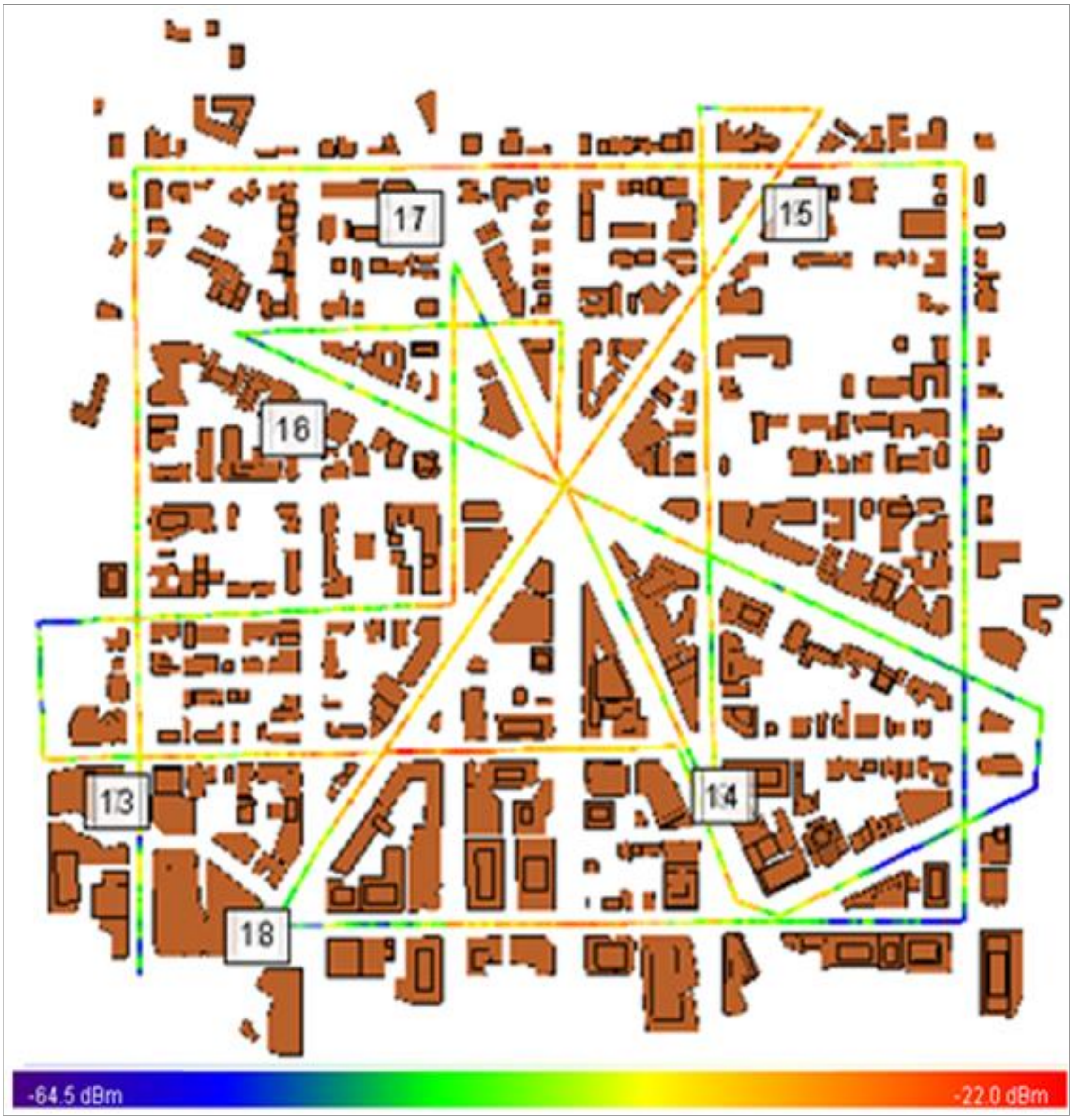

Figure 43. Best Server signal level before adjustment

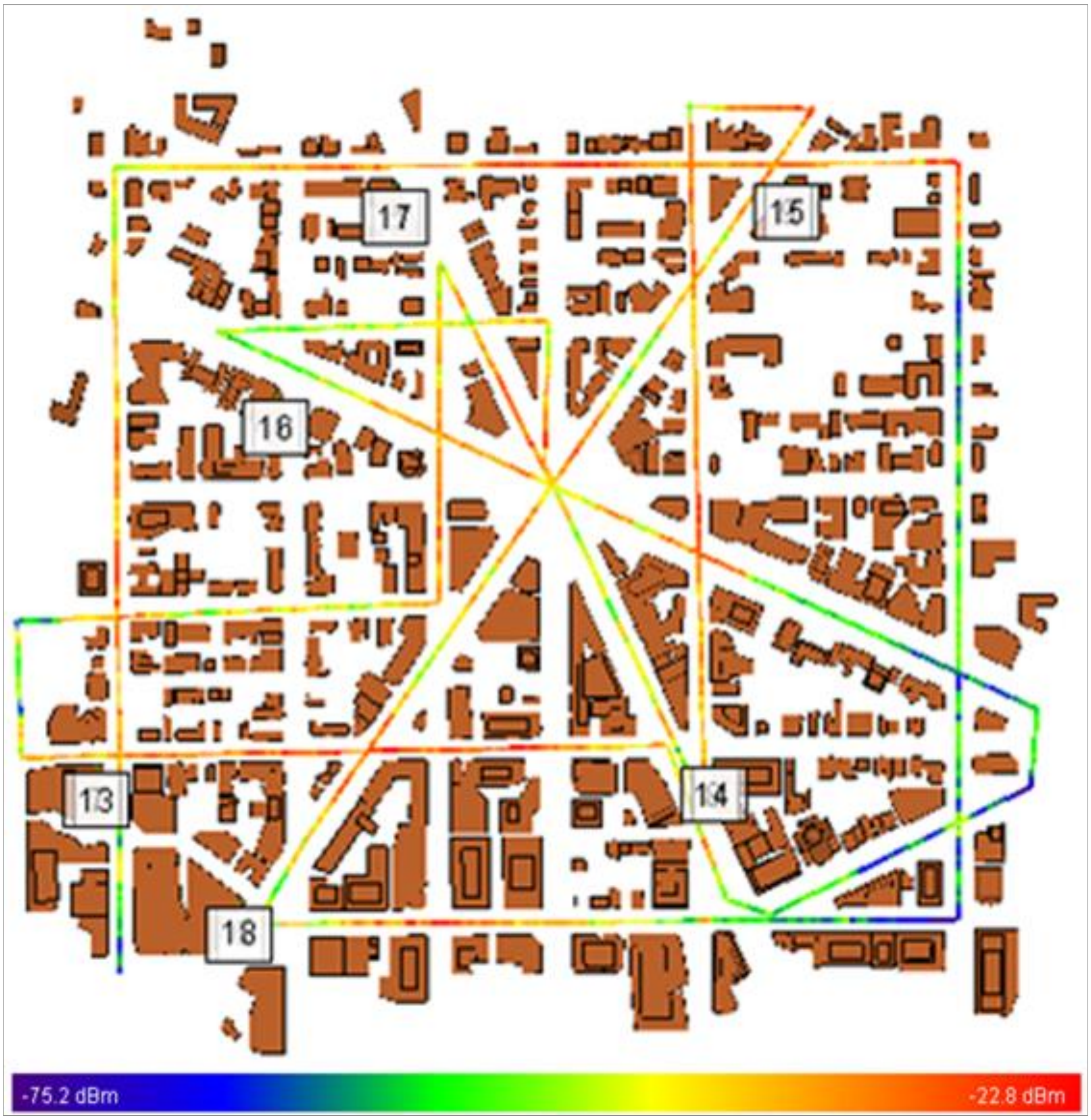

Figure 44. Best Server signal level after adjustment

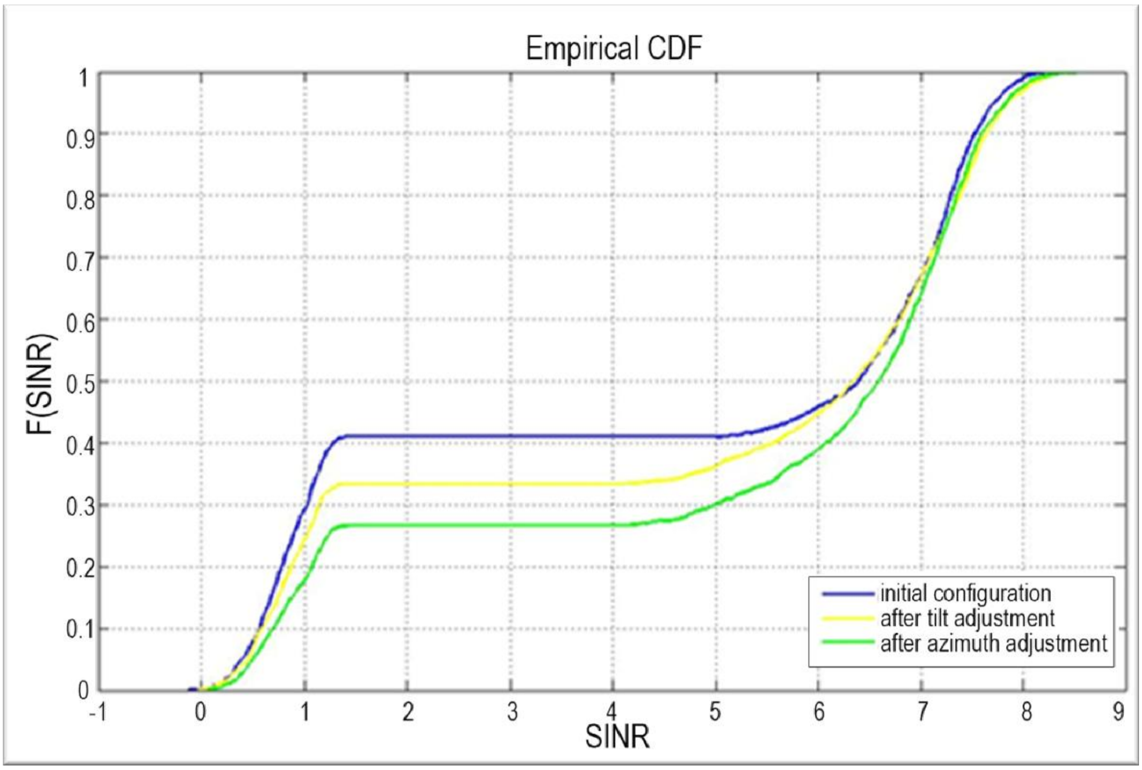

Figure 45. SINR CDF before and after adjustment

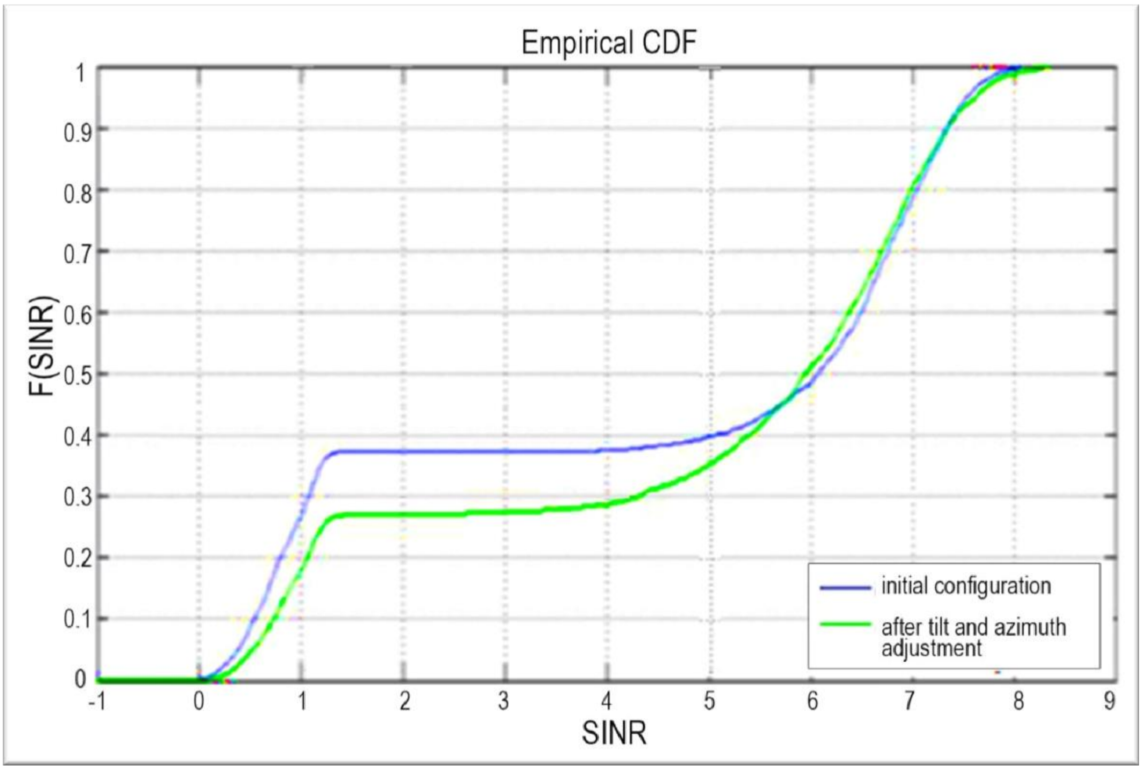

Figure 46. CDF of SINR on XY grid before and after adjustment

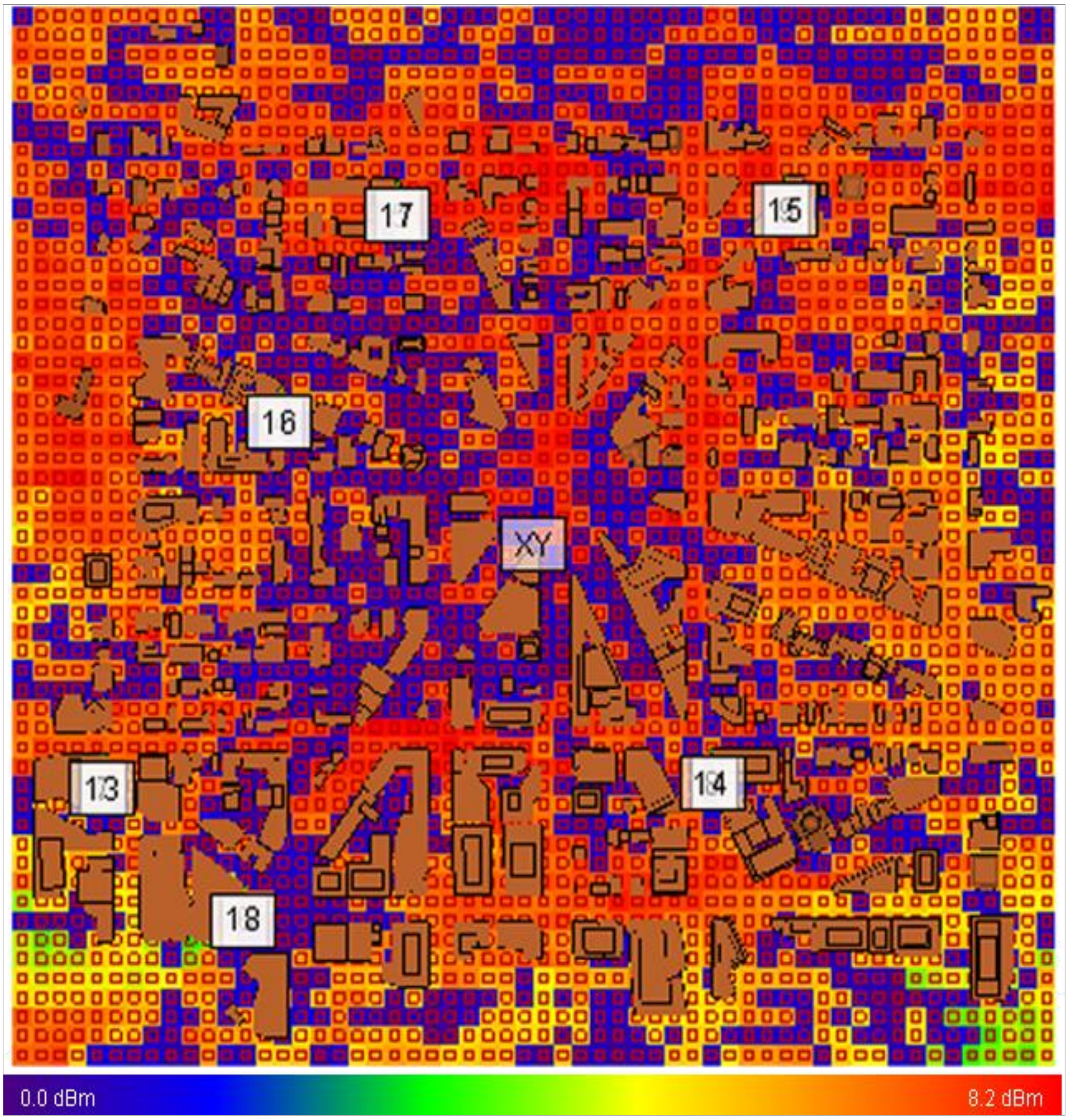

Figure 47. Overall SINR before adjustment

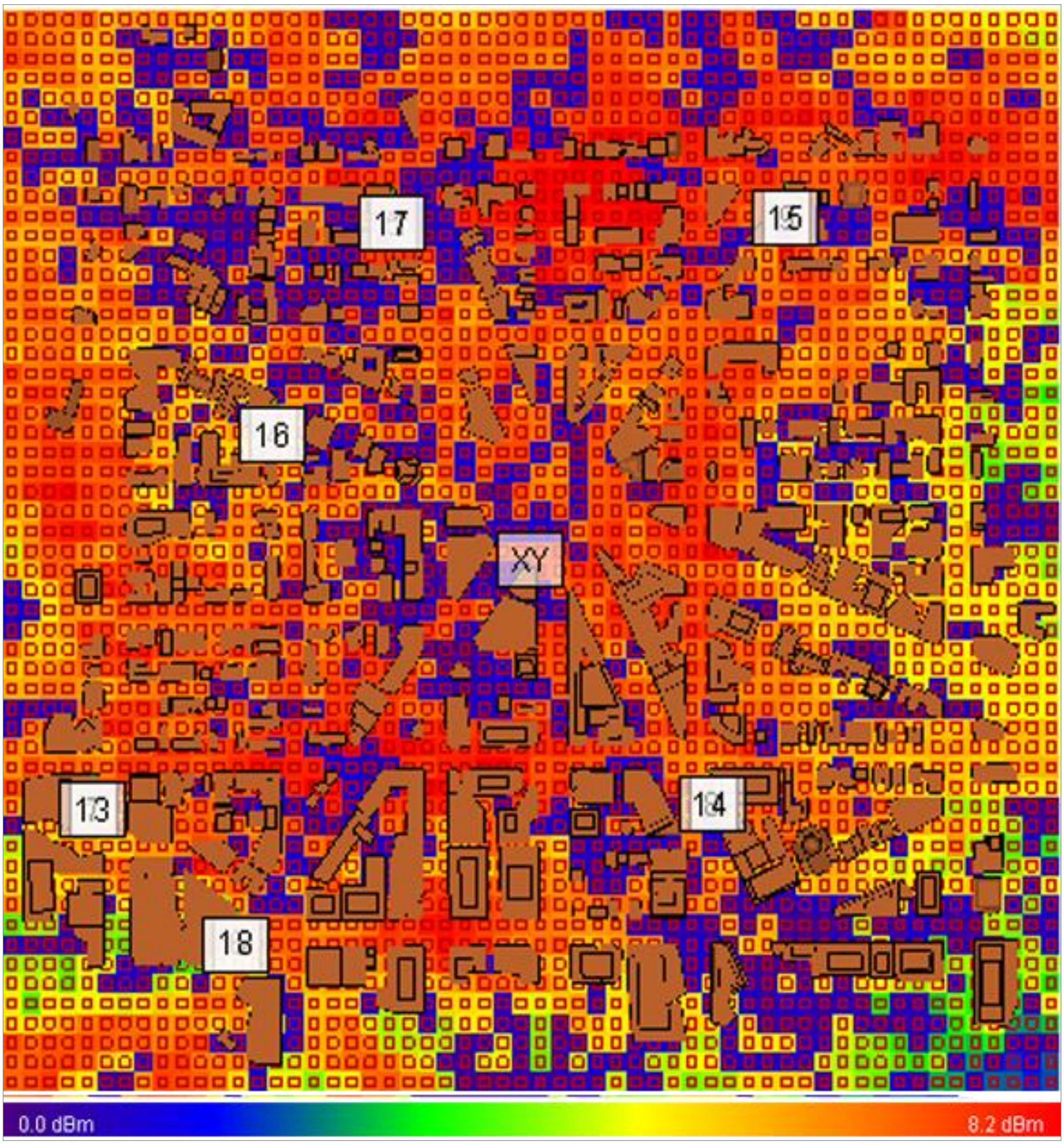

Figure 48. Overall SINR after adjustment

Scenario 2

The second simulation is again carried out on Dupont Circle, Washington city map provided by the Wireless InSite tool's examples using 6 Node Bs placed the same locations as in Scenario 1 each having 3 sector and 364 randomly placed receivers as shown in Figure 49. Initial configurations for the sites are written in Table 12. After applying the algorithm, the adjusted site configuration results are shown in Table 13. The site, sector, antenna, active set and frequency spectrum information of the simulation are the same as Scenario 1 and shown in Table 11.

Table 12. Initial site configurations

	Site 1	**Site 2**	**Site 3**	**Site 4**	**Site 5**	**Site 6**
Azimuths (degrees)	0, 90, 180	0, 100, 180	0, 180, 225	0, 270, 320	0, 180, 280	0, 60, 250
Height (meters)	46	51	43	52	55	49
Tilts (degrees)	6, 6, 6	6, 6, 6	6, 6, 6	6, 6, 6	6, 6, 6	6, 6, 6
CPICH Power (dBms)	36,36,36	36,36,36	36,36,36	36,36,36	36,36,36	36,36,36

Table 13. Adjusted site configuration

	Site 1	**Site 2**	**Site 3**	**Site 4**	**Site 5**	**Site 6**
Azimuths (degrees)	358.5, 74.5, 180	358, 91, 220.5	356.5, 190.5, 230.5	355, 273, 321.5	352.5, 181.5, 282.5	357.5, 51.5, 260
Tilts (degrees)	10, 11, 6	6, 11, 10	9, 12, 12	10, 10, 12	12, 6, 8	12, 11, 7
CPICH Power (dBms)	36, 36, 36	36, 36, 36	36, 36, 36	36, 36, 36	36, 36, 36	36, 36, 36

Figure 49. Simulation area

Simulation Results of Scenario 2

As can be seen from the Figure 50 and 51, average SINR is equal to 3.123 and the number of measurement points under threshold is 54 before the adjustments are applied. After the configuration given by Interference Cancellation algorithm is applied average SINR is increased to 3.924 dB and the number of measurement points under threshold is decreased to 17. After that, Azimuth Adjustment algorithm is applied. Average SINR is increased to 4.102 dB and the number of measurement points under threshold is decreased to 11. Further, the average number of interferer cells on measurement points is decreased from 2.03 to 1.07 referring 47% reduction. In Figure 52, CDF of SINR before and after adjustment is given.

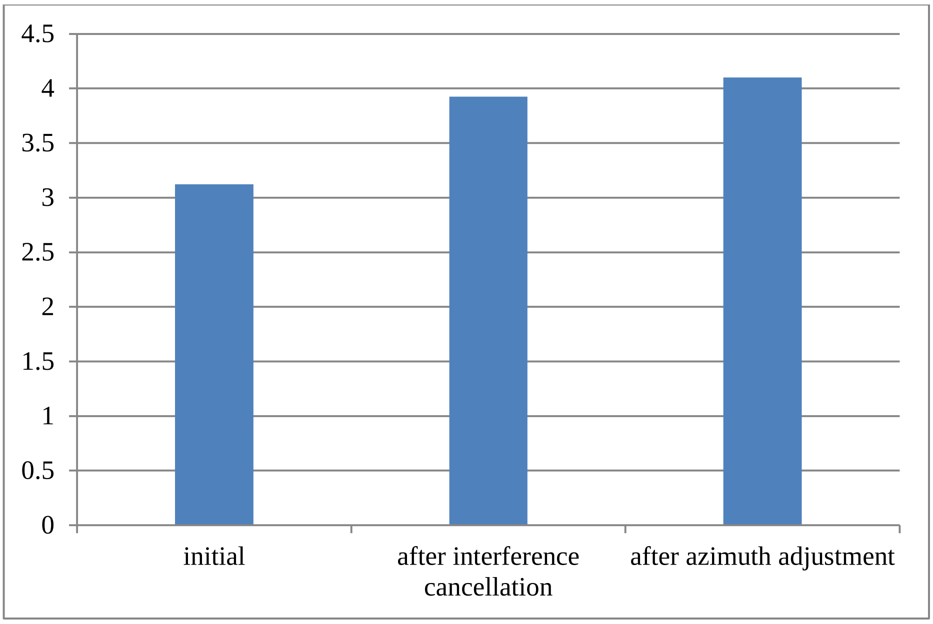

Figure 50. Average SINR

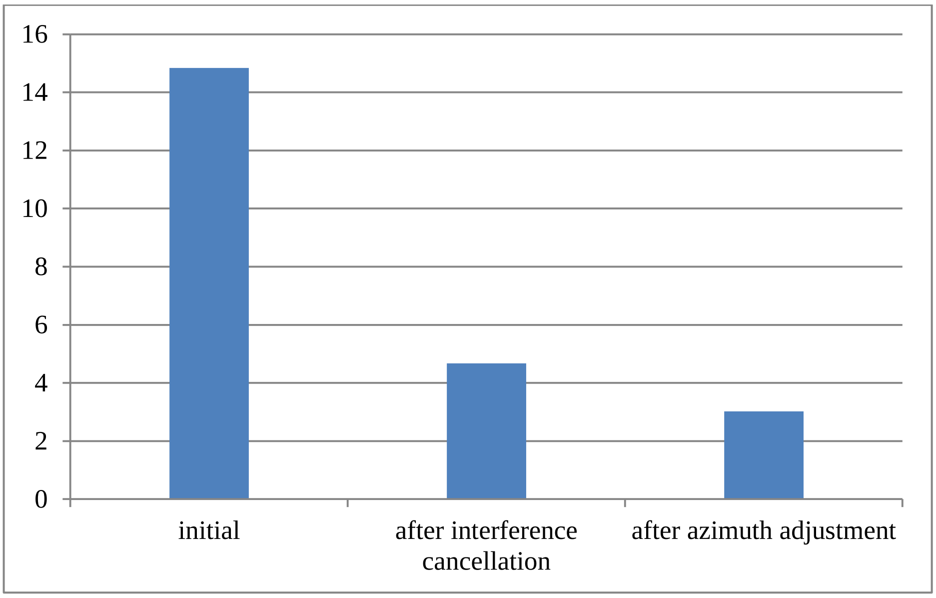

Figure 51. Percentage of MPs under threshold

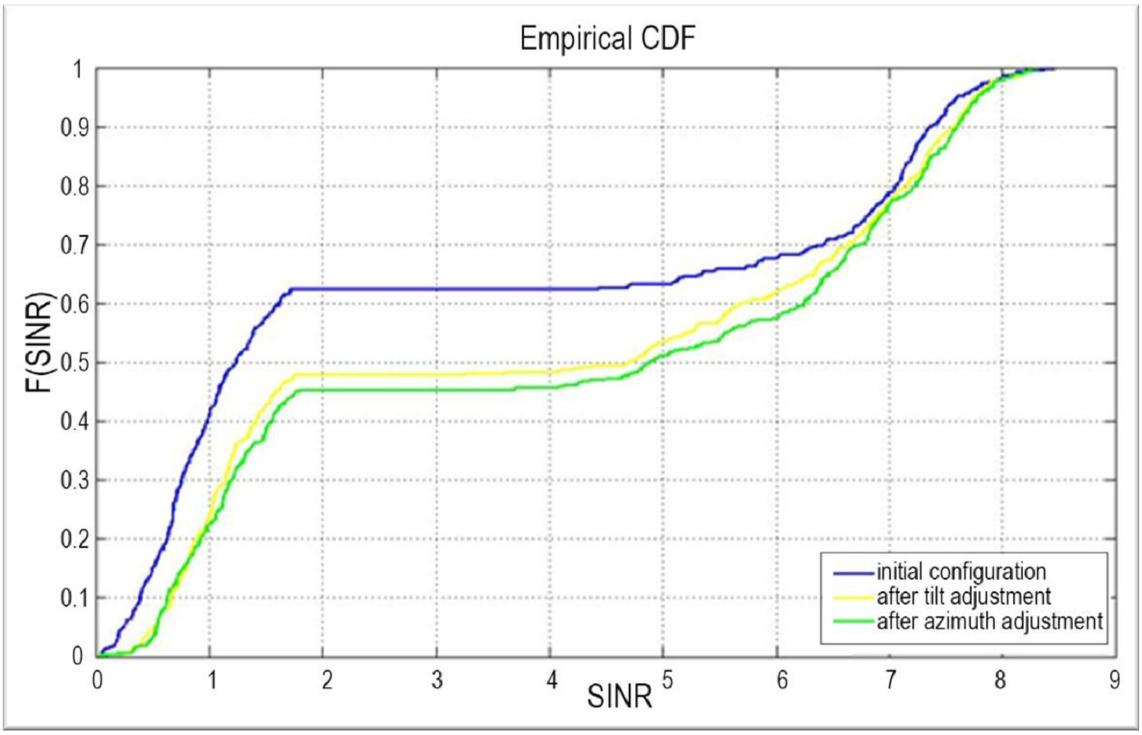

Figure 52. CDF of SINR before and after adjustment

Scenario 3

The second simulation is again carried out on Dupont Circle, Washington city map provided by the Wireless InSite tool's examples using the same site configurations. Initial configurations for the sites are written in Table 14. Only the locations of measurement points are changed as shown in Figure 53. After applying the algorithm, the adjusted site configuration results are shown in Table 15. The site, sector, antenna, active set and frequency spectrum information of the simulation are shown in Table 11.

Table 14. Initial site configurations

	Site 1	**Site 2**	**Site 3**	**Site 4**	**Site 5**	**Site 6**
Azimuths (degrees)	0, 90, 180	0, 100, 180	0, 180, 225	0, 270, 320	0, 180, 280	0, 60, 250
Height (meters)	46	51	43	52	55	49
Tilts (degrees)	6, 6, 6	6, 6, 6	6, 6, 6	6, 6, 6	6, 6, 6	6, 6, 6
CPICH Power (dBms)	36,36,36	36,36,36	36,36,36	36,36,36	36,36,36	36,36,36

Table 15. Adjusted site configurations

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Azimuths (degrees)	358.5, 74.5, 180	358, 91, 220.5	356.5, 190.5, 230.5	355, 273, 321.5	352.5, 181.5, 282.5	357.5, 51.5, 260
Tilts (degrees)	10, 11, 6	6, 12, 12	12, 12, 12	11, 9, 12	12, 7, 12	12, 12, 6
CPICH Power (dBms)	36, 36, 36	36, 33, 33	33, 33, 33	36, 36, 33	36, 36, 33	36, 33, 36

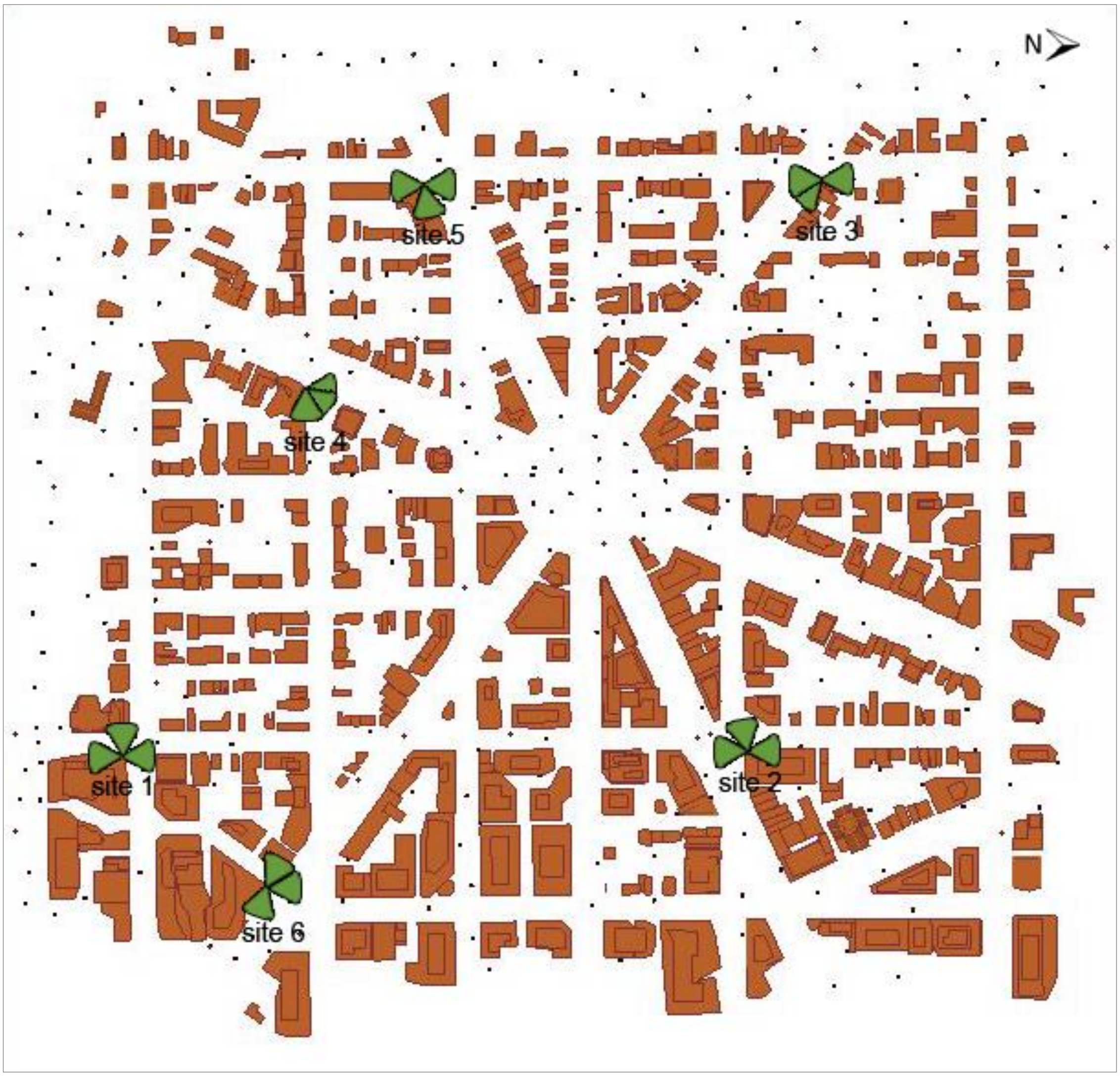

Figure 53. Simulation area

Simulation Results of Scenario 3

As can be seen from the Figure 54 and 55, average SINR is equal to 3.310 and the number of measurement points under threshold is 44 before the adjustments are applied. After the configuration given by Interference Cancellation algorithm is applied average SINR is increased to 4.312 dB and the number of measurement points under threshold is decreased to 13. After that, Azimuth Adjustment algorithm is applied. Average SINR is increased to 4.321 dB and the number of measurement points under threshold is decreased to 11. Further, the average number of interferer cells on measurement points is decreased from 1.98 to 0.92 referring 54% reduction. In Figure 56, CDF of SINR before and after adjustment is given.

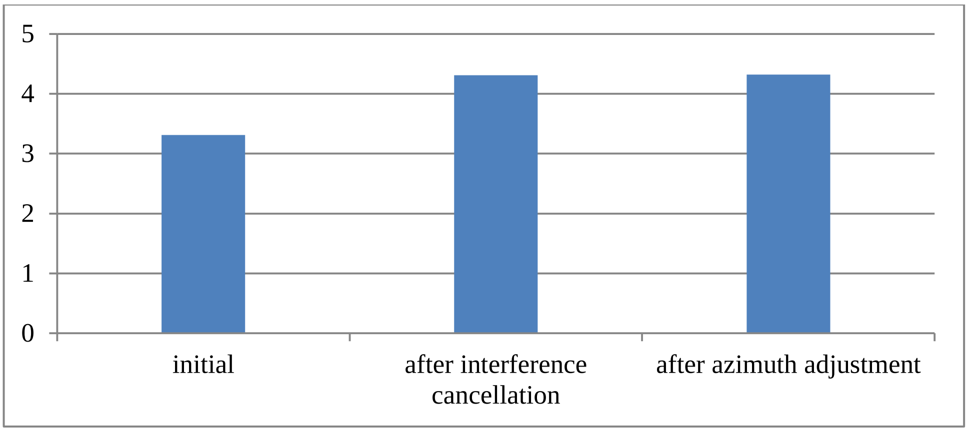

Figure 54. Average SINR

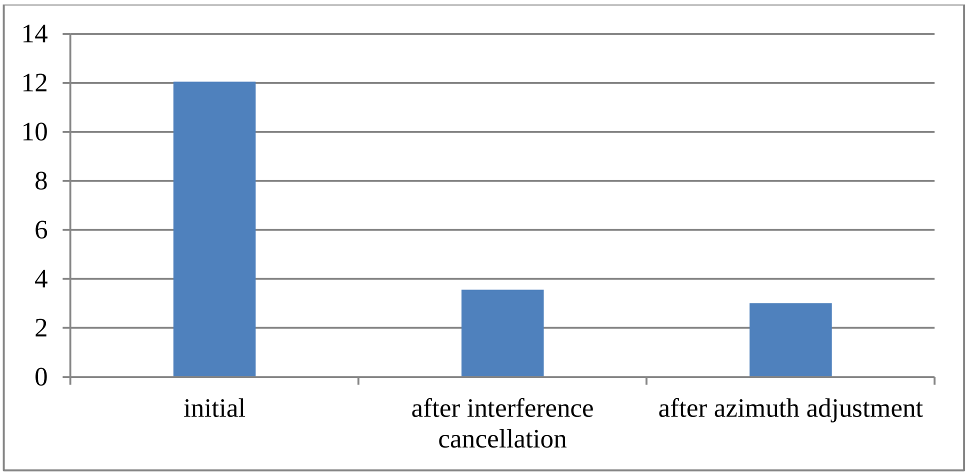

Figure 55. Percentage of MPs under threshold

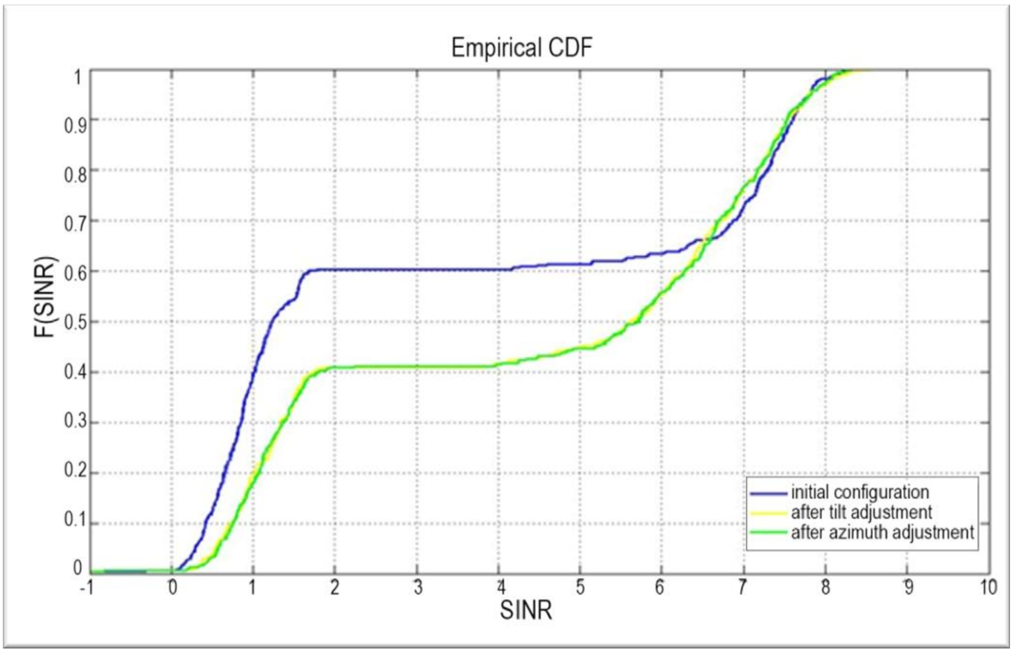

Figure 56. CDF of SINR before and after adjustment

Scenario 4

The second simulation is carried out on Rosslyn area in Northern Virginia state of United States, map of which is provided by the tool's examples using 7 Node Bs each having 3 sector and 611 receivers placed with 5 meter intervals. Initial configurations for the sites are written in Table 16. After applying the algorithm, the adjusted site configuration results are shown in Table 17. The site, sector, antenna, active set and frequency spectrum information of the simulation are again the same in Scenario 1 but the number of sites is 7.

Table 16. Initial site configurations

	Site 1	**Site 2**	**Site 3**	**Site 4**	**Site 5**	**Site 6**	**Site 7**
Azimuths (degrees)	20, 90, 330	45, 100, 280	90, 180, 270	90, 130, 260	90, 260, 350	190, 270, 350	190, 270, 350
Height (meters)	50	40	40	40	40	40	40
Tilts (degrees)	4, 4, 4	4, 4, 4	4, 4, 4	4, 4, 4	4, 4, 4	4, 4, 4	4, 4, 4
CPICH Power (dBms)	36,36,36	36,36,36	36,36,36	36,36,36	36,36,36	36,36,36	36,36,36

Table 17. Adjusted site configuration

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7
Azimuths (degrees)	18,88,5, 329	41,5,88, 280,5	90,180,270	90, 130, 263	107,5, 261,5, 346,5	195, 268, 347	190, 270,5, 348,5
Tilts (degrees)	4, 11, 4	12, 12, 4	4, 12, 5	12, 12, 5	4, 9, 12	5, 12, 4	8, 5, 4
CPICH Power (dBms)	36,36,36	36,36,36	36,36,36	36,36,36	36,36,36	36,36,36	36,36,36

Simulation Results of Scenario 4

As can be seen from the Figure 57 and 58, average SINR is equal to 5.164 and the number of measurement points under threshold is 30 before the adjustments are applied. After the configuration given by Interference Cancellation algorithm is applied average SINR is increased to 5.558 dB and the number of measurement points under threshold is decreased to 25. After that, Azimuth Adjustment algorithm is applied. Average SINR is increased to 5.567 dB and the number of measurement points under threshold is decreased to 20. Further, the average number of interferer cells on measurement points is decreased from 0.56 to 0.51 referring 9% reduction.

The SINR value on measurement points before and after tilt and azimuth adjustment is shown in Figure 59, 60 and 61 respectively. In Figure 62, Cumulative Distribution Function (CDF) of SINR before and after adjustment is given.

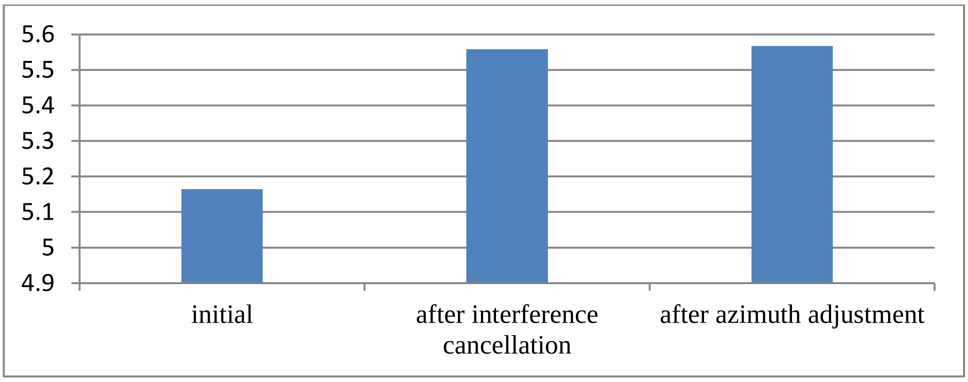

Figure 57. Average SINR

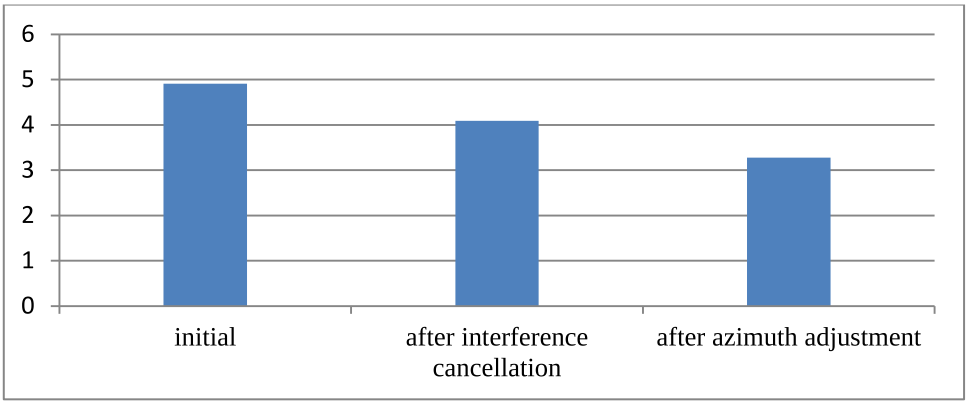

Figure 58. Percentage of MPs under threshold

Figure 59. SINR values before adjustment

Figure 60. SINR values after tilt adjustment

Figure 61. SINR values after azimuth adjustment

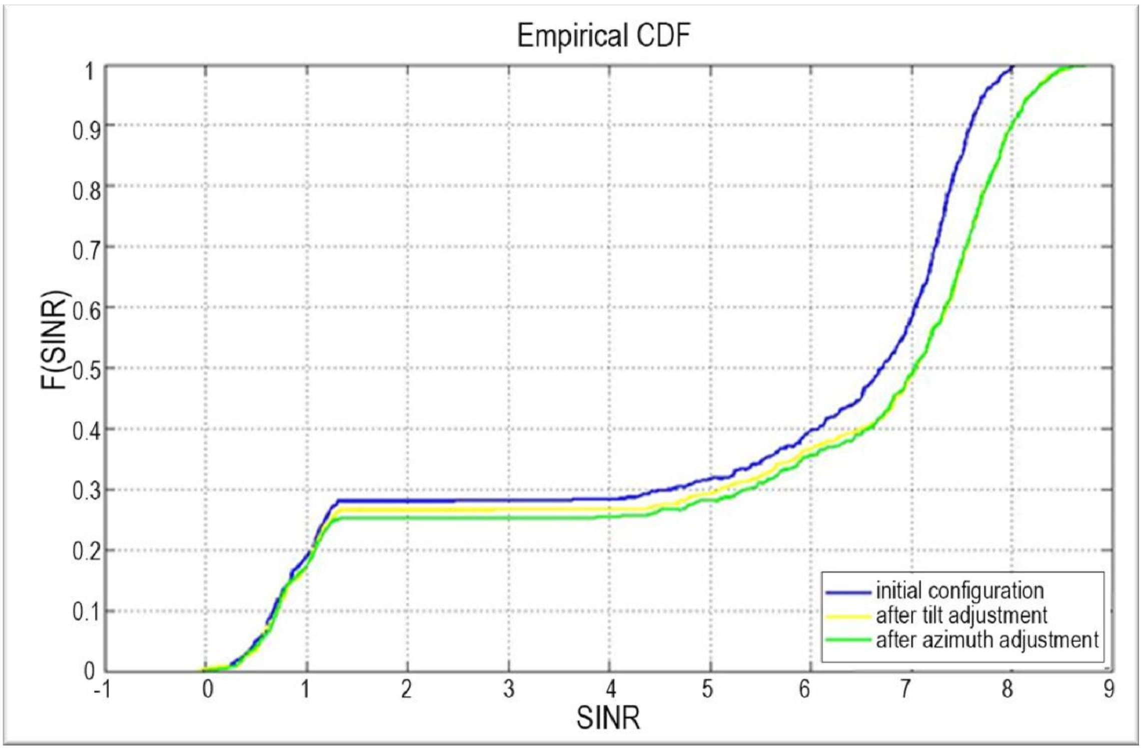

Figure 62. SINR CDF before and after adjustment

The proposed algorithm is applied on four different scenarios with two different methods and the effect of pilot power, antenna tilt and azimuth orientation according to SINR on downlink is examined.

The first method is taking the received power measurements with DT method as applied on scenario 1 and 4. It is seen that up to 20% increase in average SINR is observed. Also the number of measurement points that SINR is under threshold is decreased.

The second method is gathering received power measurements from users randomly placed on map as in scenario 2 and 3. In this method, it is possible to adjust tilt, pilot power and azimuths according to real user distribution. This advantage is appeared on results in that average SINR is increased up to 30% and the number of measurement points under SINR threshold decreased dramatically.

Moreover, scenario 2 and 3 are used also in section 3.9 to simulate the algorithm proposed in [15]. When compared with respect to signal quality, as can be seen in Figure 64 and 65, our proposed algorithm has larger increase on SINR and number of users over minimum SINR threshold. Also, the algorithm in [15] reaches the results after six iterations while the proposed algorithm in this thesis has only two steps.

However, it is important to denote that the main target of the algorithm proposed in [15] is to make uniform load distribution and decrease CDR and BCR due to congestion.

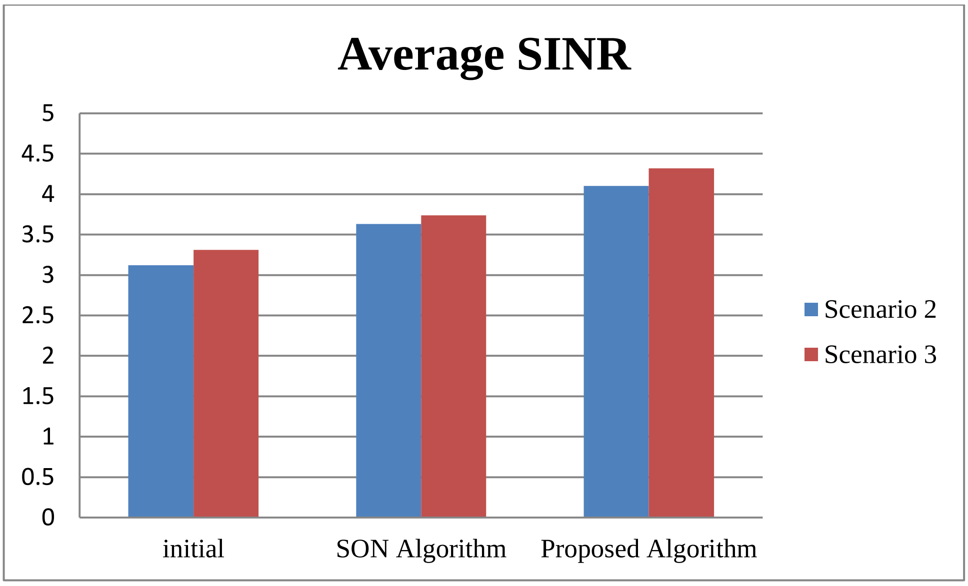

Figure 63. Average SINR Comparison

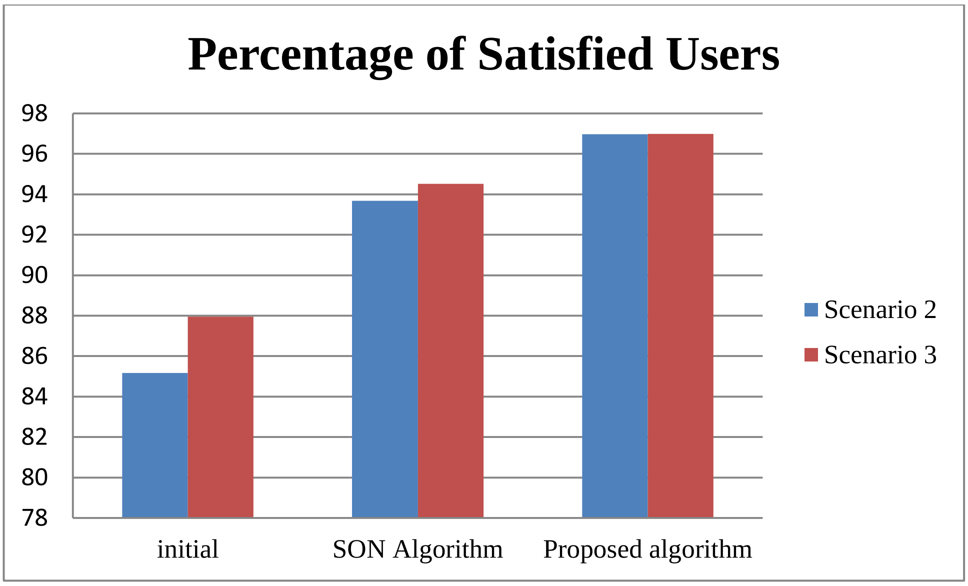

Figure 64. Satisfied user percentage comparison

CHAPTER 5

CONCLUSION

In UMTS networks, due to the common usage of the bandwidth and dense site deployment requirement, interference management is crucial. As frequently used parameters in managing interference, it is required to present a method to adjust antenna tilt, pilot power and azimuth.

In this thesis we have presented an approach to adjust and implement antenna tilts, azimuths and transmit powers in UMTS Networks based on DT measurements and has showed the effect of these configuration parameters on the interference and system. Since this performance is carried out by only two steps, it is more applicable compared to iterative algorithms.

Furthermore, another accomplished result of the simulation is to save from the transmit power and decreased the standard deviation of SINR. Thus, it will also balance load sharing among the cells. Furthermore, the power saved from CPICH power can be used by dedicated traffic channels playing crucial role concerning the capacity. Lastly, all these improvements not only increase the service quality but also bring about rise the quality of the mobility ability of the network in terms of handover success rate, which is the main target of wireless networks.

On the other hand, as future works, the algorithm can be developed by using other information such as KPI statistics (especially handover success rates between cells) and applying up tilt when needed. Moreover, in some cases, it can suggest a new site to cover a problematic area. In addition, other simulation tools developed for UMTS Networks can be used to illustrate more detailed performance results.

As a result, it is clearly shown that SINR based tilt, azimuth, and CPICH power optimization algorithms deserves consideration providing higher quality of service, less optimization cost and efficient power usage.

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