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PERFORMANCE ANALYSIS OF UPLINK THROUGHPUT WITH CHANGING ACTIVE SET SIZE IN CELLULAR RADIO SYSTEMS

İSMET ÇAĞDAŞ SOY

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PERFORMANCE ANALYSIS OF UPLINK THROUGHPUT WITH CHANGING ACTIVE SET SIZE IN CELLULAR RADIO SYSTEMS

HÜCRESEL RADYO SİSTEMLERİNDE AKTİV SET SAYISI DEĞİŞİMİNE BAĞLI YUKARI YÖNLÜ DATA HIZI PERFORMANS ANALİZİ

İSMET ÇAĞDAŞ SOY

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Chairman : Assoc. Prof. Dr. Mustafa DOĞAN

Member (Supervisor) : Asst. Prof Dr. Alparslan Çağrı YAPICI

Member : Asst. Prof. Dr. Serap Altay ARPALI

APPROVAL
…./02/2017

Prof. Dr. Emin AKATA
Director
Institute of Science and Engineering

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Öğrencinin Adı, Soyadı : İsmet Çağdaş Soy

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Danışmanın Unvanı/Adı, Soyadı : Yrd. Doç. Dr. A. Çağrı Yapıcı

Tez Başlığı : Hücresel Radyo Sistemlerinde Aktiv Set Sayısı Değişimine Bağlı Yukarı Yönlü Data Hızı Performans Analizi

Yukarıda başlığı belirtilen Yüksek Lisans/Doktora tez çalışmamın; Giriş, Ana Bölümler ve Sonuç Bölümünden oluşan, toplam 58 sayfalık kısmına ilişkin,10 /02/ 2017 tarihinde şahsım/tez danışmanım tarafından TURNITIN adlı intihal tespit programından aşağıda belirtilen filtrelemeler uygulanarak alınmış olan orijinallik raporuna göre, tezimin benzerlik oranı %11'dir.

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ÖZ

HÜCRESEL RADYO SİSTEMLERİNDE AKTİV SET SAYISI DEĞİŞİMİNE BAĞLI YUKARI YÖNLÜ DATA HIZI PERFORMANS ANALİZİ

İsmet Çağdaş Soy
Başkent Üniversitesi Fen Bilimleri Enstitüsü
Elektrik-Elektronik Mühendisliği Anabilim Dalı

Genişband Kod Bölmeli Çoklu Giriş, yüksek yukarı yönlü data transferini destekler. Yumuşak geçiş, servislerin devamlılığına ve genişletilmiş kaliteye yardımcı olur. Hücresel ağ performansı yumuşak geçiş parametresine bağlıdır. Bu tez çalışmasında, WCDMA hücresel ağlarında yumuşak geçiş parametrelerinin etkisini göreceğiz. Biz, bu çalışma boynunca, bir yumuşak geçiş parametresi olan “max Active Set Size”’a odaklandık.
Çok kullanışlı bir istatistiki ölçüm olarak actif set boyutu ve yukarı yönlü bilgi aktarım hızı kullanıldı.Bu sayısal sonuçlar yukarı yönlü bilgi aktarım hızı ve yumuşak geçiş bölgesi üzerinde belirleyici etkisi olduğunu gösterir dolayısıyla da yumuşak geçiş algoritmasının genel performansı üzerinde.

ANAHTAR SÖZCÜKLER: hücresel sistemler, yukarı yönlü data hızı, sinyal kalitesi, sinyal seviyesi, aktive set sayısı,
Danışman: Yrd.Doç.Dr. A.Çağrı Yapıcı, Başkent Üniversitesi, Elektrik-Elektronik Mühendisliği Bölümü.

ABSTRACT

PERFORMANCE ANALYSIS OF UPLINK THROUGHPUT WITH CHANGING ACTIVE SET SIZE IN CELLULAR RADIO SYSTEMS

İsmet Çağdaş Soy
Başkent University Institute of Science & Engineering
The Department of Electrical and Electronics Engineering

Wideband Code Division Multiple Access supports high uplink speeds. Soft handover, that helps continuity services and enhanced quality. Cellular networks performance depends upon Soft handover parameters. In this thesis, the effect of soft handover parameters on the performance of WCDMA cellular networks, is shown. Focused Soft handover parameter is “max Active Set Size” during this study. A very useful statistical measure for characterizing the performance of WCDMA cellular system is the active set size and uplink throughput. It is shown through numerical results that this parameter have decisive effect on uplink data speed performance and soft handover region, hence on the overall performance of the soft handover algorithm.

KEY WORDS: cellular systems, uplink data throughput, signal quality, active set size,
Advisor: Yrd.Doç.Dr. A.Çağrı Yapıcı, Başkent Üniversitesi, Elektrik-Elektronik Mühendisliği Bölümü.

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SYMBOLS AND ABBREVIATIONS

3G	3rd Generation
ITU	International Telecommunication Union
WCDMA	Wideband Code Division Multiple Access
3GPP	3G Partnership Project
UMTS	Universal Mobile Telecommunication System
WB	Wideband
DL	Downlink
UL	Uplink
HSPA	High Speed Downlink/Uplink Packet Access
QoS	Quality of Service
GSM	Global System for Mobile Communication
MS	Mobile subscriber
UE	User Equipment
SHO	Soft Handover
AS	Active set
BS	Base Station
HSUPA	High-Speed Uplink Packet Access
RSCP	Received Signal Code Power
BER	Bit-Error Rate
E_c/N_o	Energy per chip to Noise Power Density
TEMS	Test Mobile System
SQL	Structured Query Language
CS	Circuit Switch
PS	Packet Switch
CDMA	Code Division Multiple Access
MHz	Mega-Hertz
Mbps	Mega bit per second
UTRAN	UMTS terrestrial radio access network
Uu	Radio interface between the mobile and the radio access network
RNC	Radio Network Controller
I_u	RNC Interface
I_{ub}	Interface between the RNC and the Node B
Node B	Term to denote a base station in UMTS terminology
GPRS	General Packet Radio Service
SIM	Subscriber identity modüle
RNS	Radio Network Sub-system
BTS	Base transceiver Station
RRC	Radio Resource Control
SfHO	Softer Handover
TDMA	Time Division Multiple Access,

FDMA	Frequency Division Multiple Access
KHz	Kilo-Hertz
TTI	Transmission Time Interval
ISI	Inter Symbol Interference
UTRA	UMTS Terrestrial Radio Access
TDD	Time Division Duplex
FDD	Frequency Division Duplex
OVSF	Orthogonal variable spreading factor
SF	Spreading Factor
SIR	Signal to Interference Ratio
E_b/N_o	Energy per bit to noise power spectral density ratio
RF	Radio Frequency
E_c/I_o	The ratio of the received/good energy to the interference/bad energy
G_p	Processing Gain
dB	Decibel
RRM	Radio Resource Management
E-DCH	Enhanced Dedicated Channel
HARQ	Hybrid automatic repeat request
E-DPDCH	E-DCH Dedicated Physical Data Channel
HHO	Hard Handover
RSSI	Received Signal Strength Indicator
CPICH	Common Pilot Channel

1. INTRODUCTION

International Telecommunication Union (ITU) is the responsible union to create of the standardization of mobile telecommunication networks.

UMTS systems uses wideband (WB) frequencies to support high data rates for mobile access technology. WCDMA provides many communication ways at the same time. Subcribes can download or upload big size files while they are using CS services at the same time. Maximum data speeds may change depend on frequency bandwith that is being used by the operators. Coverage or capacity should adjust each others in WCDMA services. This is called cell breathing. There are many optimization features and parameters to adjust networks defined by 3GPP.

WCDMA systmes are interference-limited. All users in the network creates interference that decrease the capacity. Coverage and capacity are integrated in 3G systems. The other big difference between GSM and UMTS is establishment of links. When the Mobile subscriber (MS) establish just one link in GSM, in UMTS service User Equipment (UE) can establish more than one (maximum 3 or 4) link and it is called Soft Handover (SHO). The number of links can be called as active set (AS) size. System performance is depended to this AS size.

Mostly usage value of active set size is 3 as a default value for the biggest operators. The problem of changing AS size is; effects many Qos parameters and resources of Base Station (BS). The aim of this thesis is to select best AS size (2-3-4) parameter for the best High Speed Uplink Packet Access (HSUPA) and QoS parameter changes.

In this thesis, importance of Active Set size in WCDMA systems and adjusting some parameters of SHO is measured and described. Initiation trigger include Received Signal Code Power (RSCP), Signal to Interference Ratio (SIR), Bit-Error Rate (BER), Energy per chip to Noise Power Density (E_c/N_o) and High-Speed Uplink Packet

Access (HSUPA). UE measures the signal levels from serving and neighboring cells and sends these measurements to serving NodeB. According to these measurements, UE adjust active set by adding, removing or replacing radio links. AS contains NodeBs that are connected with UE. Thus soft handover regions occurs between NodeBs. Soft handover algorithm works to change AS during the calls.

Measurements were conducted in UMTS system in Turkey. For measurements TEMS Investigation and Ericsson Z750 phones are used with a car driving in a city. Actix and OPTIMA (SQL based statistic tool) is used to see the test results. With respect to these measurements and analysis, a new method is proposed for cellular operators.

2. UNIVERSAL MOBILE TELECOMMUNICATION SYSTEM (UMTS)

The Universal Mobile Telecommunication System (UMTS) is the one of 3G communication systems. High data transfers are possible with UMTS and it make possible high quality video streaming. UMTS is a good way for succesfull video or voice calls, live video games and high speed data transfers. UMTS uses packet switched (PS) or circuit switched (CS). WCDMA is an access technology and being used for UMTS.

2.1 UMTS System Architecture

2.1.1 User equipment (UE)

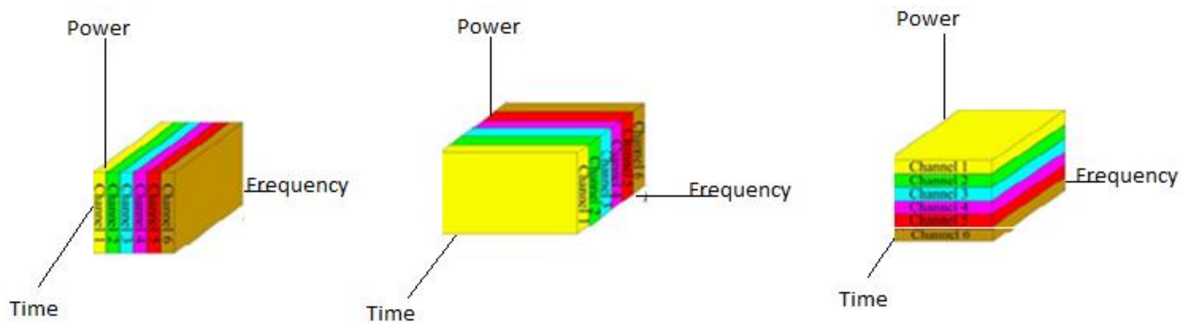
The phones or data cards in WCDMA systmes are called as User Equipment (UE). UMTS Subscriber Identity Modules (USIMs) are used inside the phones for WCDMA. Thus, the UE is the phone, and the USIM is “smartcard”. There are some secure improvements on USIM for 3G.

2.1.2 Spherical wave

Universal Terrestrial Radio Access Network (UTRAN) contains RNSs (Radio Network Sub-system). RNS contains NodeBs with Radio network controllers (RNC). NodeB is a cabinet that is used for the radio transmission. Function of NodeB is to provide radio link between the interfaces (Uuo r Iu) in downlink and uplink. NodeB also calculates dowlink transmission power control. RNC controls the NodeBs under itself and main tasks are mobility and radio resource managements. Some other tasks of RNCs are; to check load and power controls. Radio network controller also manages data transfers between interfaces (Iu, Iur, Iub).

2.2 WCDMA Radio Interface

Figure 2.1 decribes the difference of access methods. As it is seen in Figure 2.1 (a), different channels are sent by different frequencies at the same time and it is named as Frequency Division Multiple Access (FDMA). In Time Division Multiple Access (TDMA), mostly one frequence is used and data is sent with same frequncy with different time. For the last picture shown in Figure 2.1 (c) Code Division Multiple Access (CDMA) can send the data at the same time on same frequency but it seperates data with different codes.



a) FDMA b) TDMA c) CDMA

Figure 2.1 Multiple Access Types (a) FDMA (b) TDMA and (c) CDMA

2.2.1 WCDMA system

Below Table 2.1 shows the specification of FDD and TDD Access methods. In this thesis, CDMA technology is used for the tested operator. Channel bandwitdh is 5MHz but it can be enhanced to 10 MHz with dual band in downlink direction. But this thesis focus point is uplink throughput so uplink bandwitdh is 5 only MHz.

Table 2.1 Access Method Differences

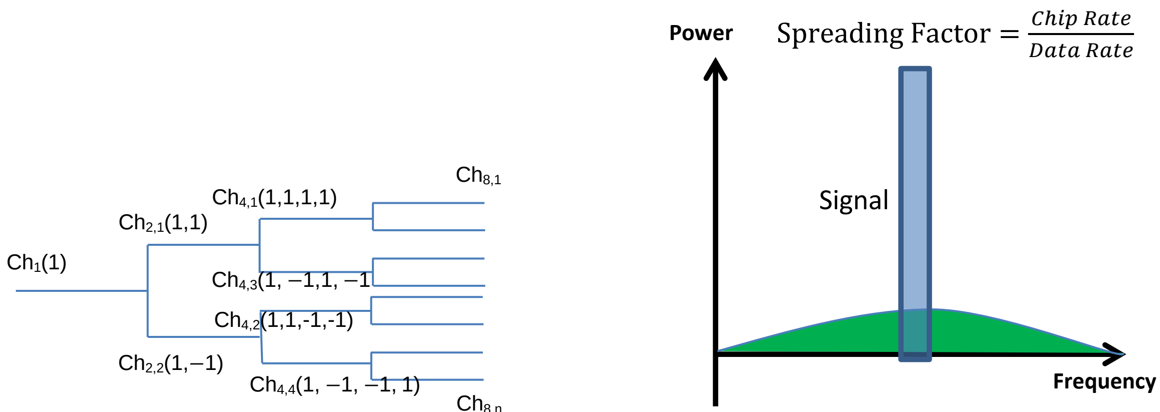
Specifications	TDD	FDD
Access Type	TDMA,CDMA	FDMA
Duplex Type	TDD	FDD
Bandwitdh	5 MHz	
Chiprate	3,84 Mcps	
Time Slot Structure	15 slot/frame	
Transmission Time Interval (TTI)	2ms or 10 ms	
Modulation	QPSK, 16QAM, 64 QAM	
Spreading Factor	1…..16	4….512
Handover Types	Hard HO	Soft HO

In this thesis, measurements are completed in Turkey’s one operator with 5 MHz bandwitdh as explained above and chip rate is 3,84 Mbps.

In WCDMA, two important codes are named as channelization and scrambling. These two codes are used to create a random data and to prevent data clashes. Because as explained above, with CDMA technology; many UEs send data packets with same frequency at the same time so this technology seperates sent data with those codes. Channelization codes are orthogonal and it is very useful to separate data channels.

Figure 2.2 (a) shows code tree for channelization and spreading signal process. As it is seen from the code tree, many user can use the same branch of the tree with low data rate or less user with high data rate. So if UE will use C8 branch, system doesn’t let other UEs to use C4 or C2 branch. Main idea of the spreading is described in Figure 2.2 (b), as its name, lower the power to decrease interference and spread the signal to the all WCDMA band.

When the UE uses low spreading factor it needs more codes, so that data rate gets higher. For instance, if the spreading factor is low and data bit rate is high, it means less users are being deducted so that this effects the capacity



a) Channelization code tree b) Spreading Signal

Figure 2.2 Channelization Code Tree and Spreading Signal

The channelization codes are orthogonality and used for the channelization. The most common definition is: perpendicular, forming a right angle of 90 degrees between the references.

Spreading factor is calculated in frequency and time domain seperately. In time domain, chip rate is a constant value and never change. So spreading factor changes with the data rate code channel.

In Time Domain;

SF = Chip Rate / Data Rate coded channel (2.1)

In Frequency Domain, spreading factor is calculated below equation. Here it is found bandwitdh of the signal divided by baseband data and bot hare in Hz format :

$$SF = \frac{W}{R} \tag{2.2}$$

The primary scrambling codes starts from 0 to 511 and they are used as reused because operators have more than 512 NodeBs. A scrambling code are given to each cell and these codes seperate NodeBs in downlink. This code is used for UEs to recognize signal belong to which NodeB. and only one primary scrambling code. So as it is seen, scrambling codes are reused due to 3GPP limit is with 512 codes. To make for UE easy the cell-search procedure it is limited with 512 for DL.In Uplink, there is not a limited resourse as we have in downlink.

Figure 2.3 describes how data bits are changed by using Scrambling codes and spreading codes on Tx and Rx side.

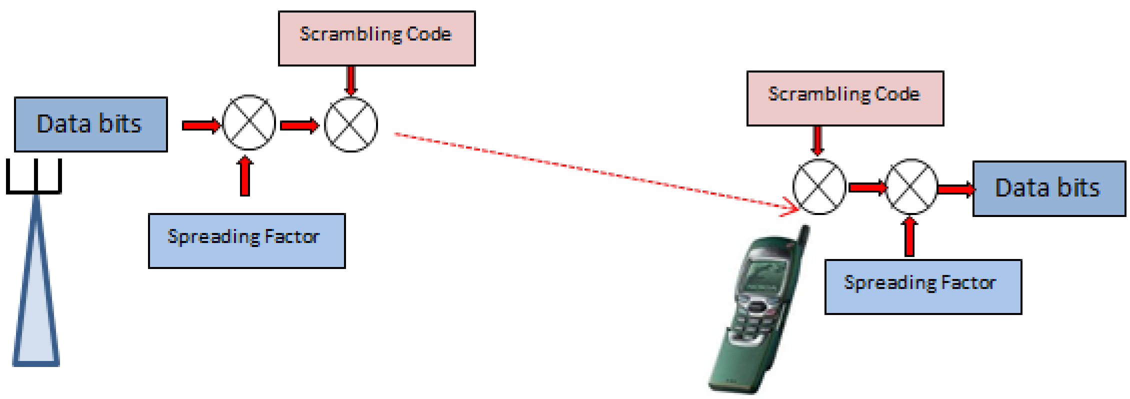


Figure 2.3 Transmission Data Process in WCDMA

Figure 2.4 shows many UE sends signals to NodeB at the same time and that creates interference. This is calculated by SIR and quality is described by E_b/N_o. Measurement results are indicated these two parameters for each measurements.

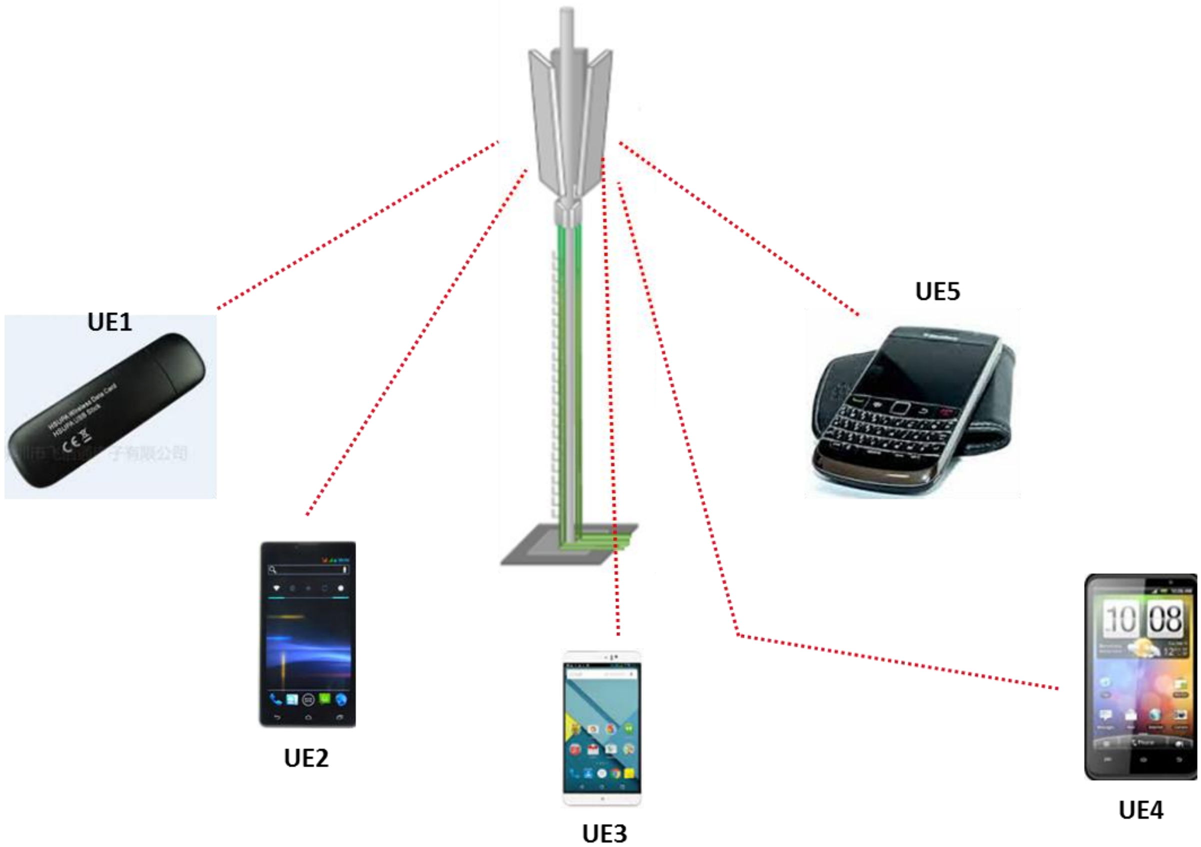


Figure 2.4 UL Signals Creates Interference

As explained above, all users creates interference in the WCDMA systems. Total power at the receiver is calculated by S*(N-1), and (N-1) is symboled as interfering signals so that signal-to-interference ratio (SIR) is;

$$SIR = \frac{S(N-1)}{S} = \frac{1}{(N-1)} \tag{2.3}$$

E_b/N_o or bit energy to noise ratio, is calculated by below equation;

$$\frac{\mathrm{Eb}}{\mathrm{No}} = \frac{\mathrm{S/R}}{(\mathrm{N}-1)\mathrm{S/Wrf}} = \frac{1}{(\mathrm{N}-1)} . \frac{\mathrm{Wrf}}{\mathrm{R}} \qquad (2.4)$$

And processing gain:

$$Gp = \frac{Total\ Spread\ BW}{Information\ Bit\ Rate} \qquad (2.5)$$

In WCDMA systems, norrow band signal is spread to wide band. So processed signal's SINR is diveded to uprocessed signal's SINR value and processing gain is found. Lower spreading factor means higher bit rate. Below the equations, shows the relationship between the SIR and E_b/N_o.

$$\frac{E_b}{N_o} = SIR \times G_p. \qquad (2.6)$$

$$SIR = \left(\frac{1}{G_p}\right) \times \left(\frac{E_b}{N_o}\right) \qquad (2.7)$$

in dBs:

$$SIR = \left(\frac{E_b}{N_o}\right) - G_p \qquad (2.8)$$

The Figure 2.5 explains how E_c/I_o gets lower when the interfere increases at a certain location. First picture shows the E_c/I_o for the only one cell is serving so for this example 2W 33 dBm is E_c and I_o is 10 W(sum of 2W, 2W, 6W) as 40 dBm so E_c/I_o is 33 dBm – 40 dBm = -7 dB.

For the second example; 5 sectors signal is reaching to UE. E_c/I_o is measured as 33dBm – 46dBm = -13 dBm. And this shows us if the received sector signal increases then E_c/I_o (quality) will be worse.

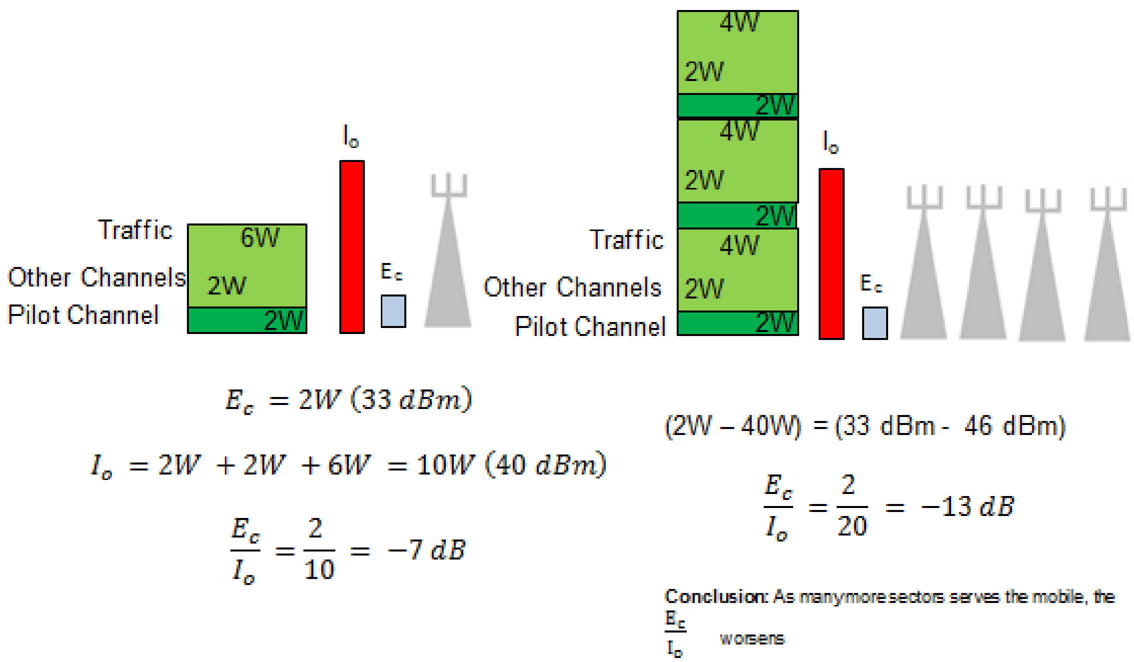


Figure 2.5 Explanation of SIR and E_c/I_o

For instance; below equation shows speech signal with a bit-rate of 12.2kbps. So Rb is a voice packet with 12.2 kbps and Rc is a constant in WCDMA as 3.84 Mchips/sec. Then the processing gain of the signal is found 25 dB as shown in below equation.

$$G_p = 10 \cdot log\left(\frac{R_c}{R_b}\right) = 10 \cdot log(3{,}84 \cdot 10^6 | 12{,}2 \cdot 10^3) = 10 \cdot log(3{,}15 \cdot 10^2) = 25\ dB \quad (2.9)$$

Original signal needs to be a few dB above the interference and noise power. E_b/N_o shows us the quality of the network.

The required signal power density below the interference power density before despreading is designated as SIR (Signal to Interference Ratio), and it is also known as E_c/I_o (In fact, E_c/I_o and E_c/N_o are the same)

To be decoded succesfully by the receiver, signal should be 5 dB higher than the noise. For this reason:

$$SIR_{target} = 5\ dB - 25dB = -20dB \qquad (2.10)$$

$$SIR + G_p = E_b/N_o \rightarrow -20dB + 25dB = 5dB \qquad (2.11)$$

And it is found noise + interference is 100 times higher than the E_c:

$$10 \cdot log(E_c/N_o) = -20\ dB \rightarrow (E_c|N_o) = 10^{-2} \rightarrow N_o = 100 \cdot E_c \qquad (2.12)$$

So even if noise is 100 times larger than the signal, SIR is enough good to be decoded by the receiver.

This thesis's aim is to monitor SIR and E_c/I_o changes with active set size. As measured different SIR values with different AS size trials and effect of HSUPA throughput.

Summarizing, below equation is in dBs:

$$SIR_{target} + G_p = \langle E_b | N_o \rangle \qquad (2.13)$$

The received SIR is negative in dB. In WCDMA networks SIR and E_c/N_o values very important and these two values give idea about network quality. If there are many interferer cells in the network both values get lower. To increase the quality, neighbour definitions are completed carefully. Also for overshooting cells can be downtilted to prevent interference. E_c/I_o values are given to show quality for thit thesis in the measurement parts.

This tells why interference is very important in the 3G networks. Operators's aim is to provide best network quality for their customers. After planning all NodeBs, drive tests measurements are important to monitor network quality. If interference is high in the network, E_c/N_o values will be low and this will effect voice and data services. So that many drops ocur in the network or data tranfer speed get lower. Also by increasing the interference, NodeBs start to narrow serving area and it is known as "cell breathing". As NodeBs serve less area, the coverage and capacity of the network decrease. This is the why capacity and coverage cannot be separated in WCDMA. [2]

2.3 Radio Resource Management

RRM (Radio Resource Management) in UMTS network is responsible for the utilization of the air interface resources. RRM is needed to; guarantee quality of service (QoS), maintain the planned coverage area and offer high capacity. It is explained under this chapter, how admission and load control is done. UE, NodeB and RNC play a role.

2.3.1 Admission and load control

As explained before, main optimization tasks are capacity and coverage in 3G systems. Cell breathing is a new concept in 3G as explained above. So that while changing the existing radio connection type or serving to a new UE, NodeB may change its own coverage. Before the NodeB will serve to a new UE, admission control function works. If NodeBs resources is enough to establish a new radio link then NodeB starts serving to that new UE and provides required channels. This calculations are done for each UL and DL direction. Thus, the admission control is the authority for rejecting or accepting new radio link in the cell. RNC is the responsible network element to calculate admission control. Because RNC collects all load information from the all NodeBs those works under. All base stations works under a RNC. As an example; some operators install a RNC for each city. For the measurements, active set size parameter is changed under RNC. When the parameter is being changed under the RNC, all cells under that RNC, works through that parameter. UE makes measurements as that parameter and according to measurements new radio links (RL) are added or removed.

Load control looks like to admission control. Task is to be sure that system will not be overloaded. In the RNC first admission control algorithm works. If admission control lets UE to be served, then load control algorithm is used. If the cell is overloaded, then load control disconnects some radio links till cell load achieves the target load. Load control can take some actions to get lower the existing load on the cell such as, denying downlink power-up commands, reducing throughput by changing SF, or dropping calls as a last result. [2; 3]

2.4 High Speed Uplink Packet Access (HSUPA)

HSUPA is the next evolution step for UMTS networks. Some vendors are named it as Enhanced Uplink (EUL). The aim of HSUPA is transmit data packets with high data rates. Many operators in the world, didn’t deploy HSUPA in the first phases of 3G. Becasue internet usage was commonly contains downlink so that High Speed Downlink Packet Access (HSDPA) was the favourite for the users and operators. But with the dissemination of using new applications all over the world, popularity of the HSUPA increased. HSUPA is the very common usage area nowadays with the popularity of requiring high uplink speeds such as Twitter, Periscope or Facebook. These applications need uploading video streaming or big size files and HSUPA provides us up to 5.76 Mbps speed. Also HSUPA has a low latency with using 2ms TTI. Also it will be seen in our measurements, how TTI usage is important to reach higher data rates in uplink direction.

2.4.1 Hybrid automatic repeat request (HARQ)

Hybrid automatic repeat request (HARQ) is being used to forward error-correcting. As a basic explanation in Figure 2.6, when NodeB sends a packet data to UE, if UE doesn’t decode the data, sends not acknowledgement (NACK) message to NodeB so that NodeB sends the packet again. If UE decodes the data packet then sends acknowledgement (ACK) message to NodeB. High NACK message ratio is cause of low data throughput.

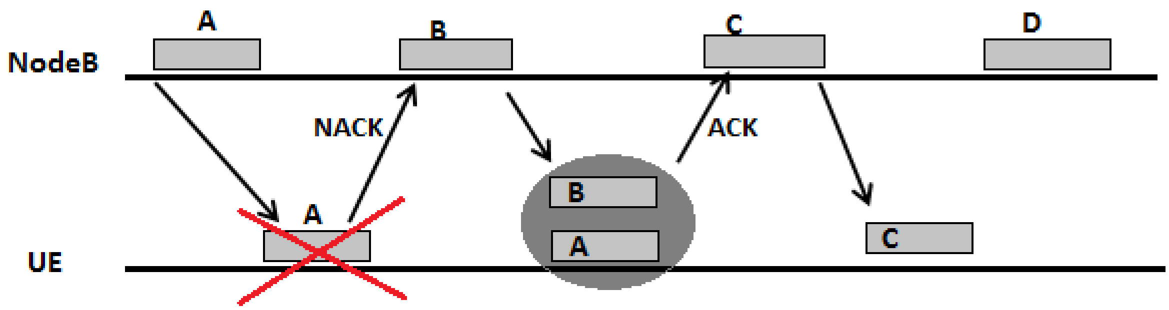


Figure 2.6 Hybrid ARQ

2.5 WCDMA Handover

Handover is very important for mobile users in the 3G systems. When subscribers change their existing location, the signal level of the serving NodeB may decrease. In this situation UE should make measurements and select the right candidate as a new serving cell. This is named as handover. Handovers provide continuty of the services while UEs are moving in cellular networks.

In 2G systems, handovers are very basic. Hard handovers (HHOs) are being used in 2G systems. In a hard handover, only one cell can serve to UE. If UE finds a better cell to be served, it releases old cell and connected to new cell. Soft handovers (SHOs) and softer handovers (SfHOs) are brought out with 3G systems. Advantages of SHO are; overcome fading with macro diversity, reduce NodeB power so that decreases interference and increase the capacity and reduce UE power (up to 4 dB) so increases battery life. Disadvantage is; UE connects more than one NodeBs and that requires more resources on the I_{ub} and I_{ur} interfaces.

Thus, handovers are very efficent in WCDMA systems. That thesis measurements show the SHO attempts such as RL addition removals or replacements.

2.5.1 Soft handover

Soft handover is; where UE is connected to two or more cells (or cell sectors) during a call at the same time. Figure 2.7 shows SHO function where the UE makes the measurements and if the algorithm lets adding new RL addition to active set then suitable cell is added to active set. If this cell is the same sector of the NodeB this is named as SfHO, if the added cell belongs to another NodeB, that is named as SHO.

This characteristic enables continuty of the services and prevent drop calls. It is possible for UEs to receive signals from two or more NodeBs. The active set size defines how many cells should be at the same time. Beacuse of the feature of WCDMA, AS size is set to 2, 3 or 4. When the SHO algorithm works, check the possibilities of addition / removal or replacament and decide according to maxactivesetsize parameter.

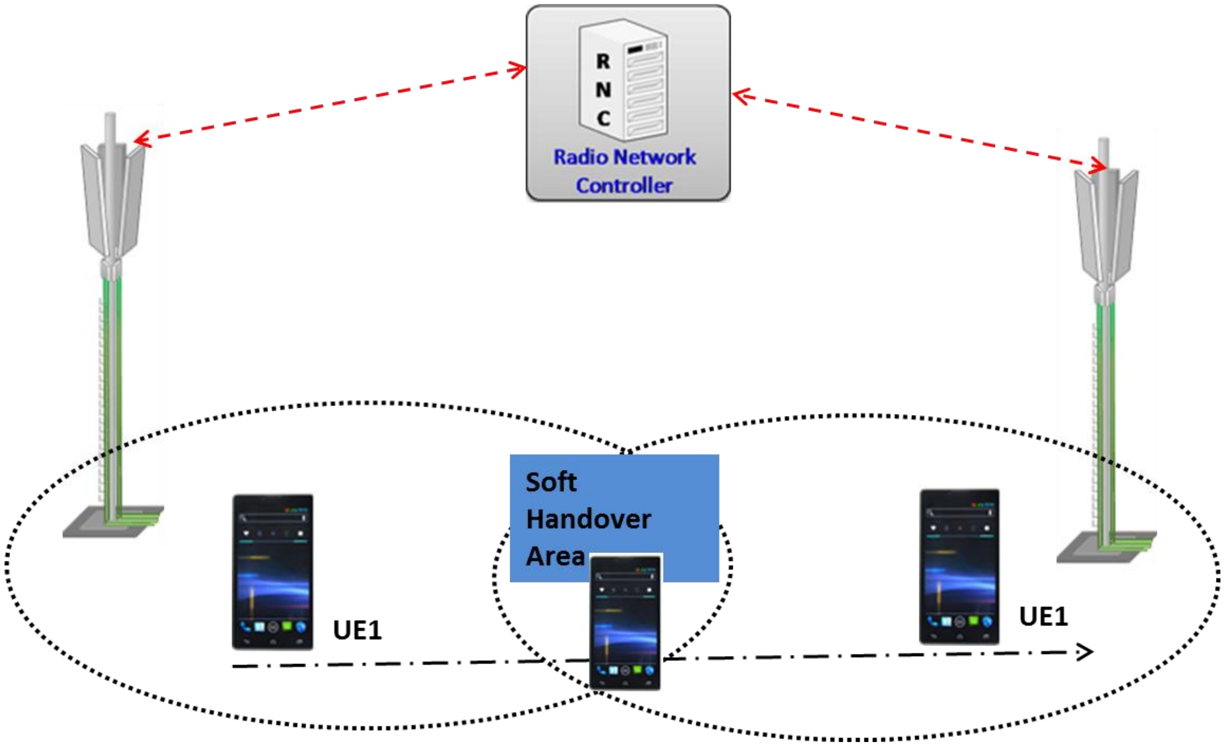


Figure 2.7 Handover Function

2.5.2 Softer handover

Softer handover looks like to soft handover. Almost same with SHO, UE connects to cells that are under the same site as shown in Figure 2.8.

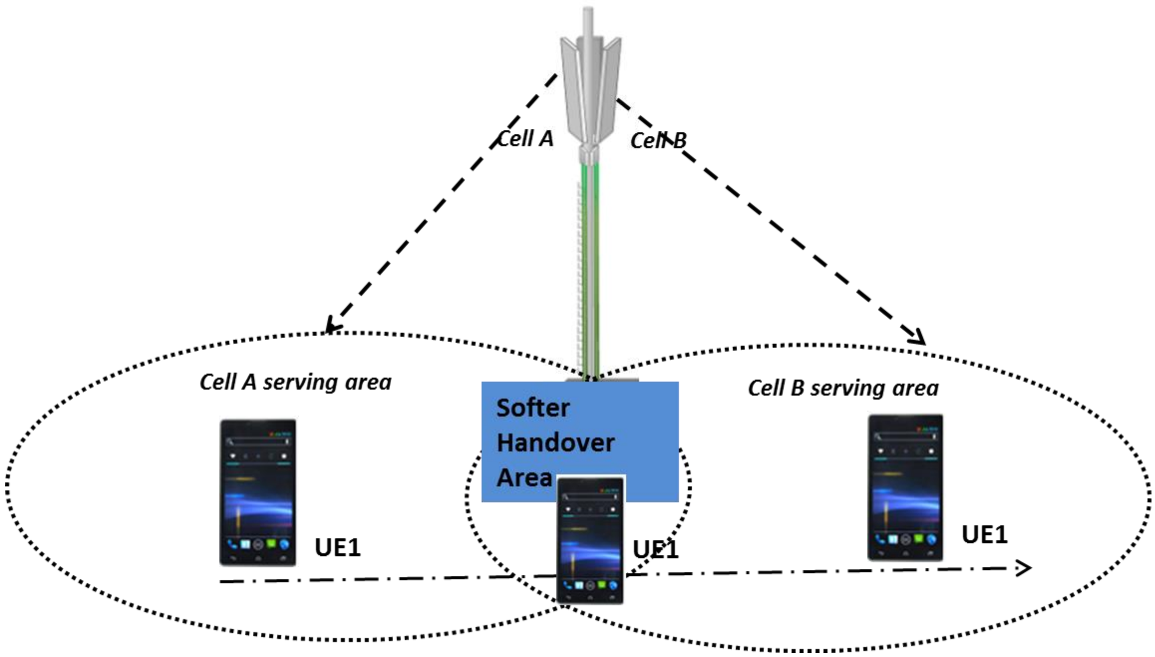


Figure 2.8 Softer Handover Function

2.5.3 Intra and inter frequency handover

In WCDMA systems, not only SHOs are being used but also hard handovers are being used for some traffic balancing between the frequencies. Operators may use more than one frequencies so UE may handover from one frequency to another. Operators can use more than one WCDMA frequency in their network so same cells can be defined with 2 frequencies. Thus if a handover ocurs between the cells that have the same frequency, it is named as “intra-frequency handover”. But if handover occurs between the cells that have different frequencies, it is named as “inter-frequency handover”.

2.5.4 Inter-system handover

As it is told above, WCDMA allows both SHO and HHO. Coverage areas of the systems may be different from each others. For instance, one operator can use 800

MHz frequency band for GSM network and 2100 MHz frequency band for WCDMA network. In that situation, even if WCDMA site count is higher than the GSM site count due to frequency difference, WCDMA coverage may be less than GSM coverage. In this case, when the 3G coverage is not enough for UEs, UE decodes other systems's frequencies such as GSM and makes handover to other system. Inter-system handovers may be used for coverage edges in the 3G and also when the 3G cell load is very high or continuty of the CS services.

3. WIRELESS SYSTEM PROPAGATION TYPES

In all wireless systems in radio signals spreads from more than one path. Signals crashes trees, buildings or even ground and receive to antenna from many paths. So that, receiver can be interfered by the same signal that are reflected. This is a big problem for wireless systems and some filters are used to measure right signals.

In this part, propagation types such as multipath propagation, fast/slow fading will be described with some formulas.

3.1 Multipath Propagation

Multipath propagation occurs on all wireless sytems and this is a big problem. Radio signals spread on the air and after they crash to obstacles, reflect. Signal is not transmitted one direction of the antenna, to reduce multipath propagation, directional antennas are used but this only reduces not eliminate all. So that, even directional antenna transmitts signals and signal reaches objects such as; hills, buildings or reflective surfaces. Then signals are reflected from the obstacles and receive the antenna via different paths. So antenna receives one signal from the main path and many reflected signals from the obstacles such as buildings, trees, ground or water.

Figure 3.1 shows a small network example with line signalling but in the reality signals reflects.

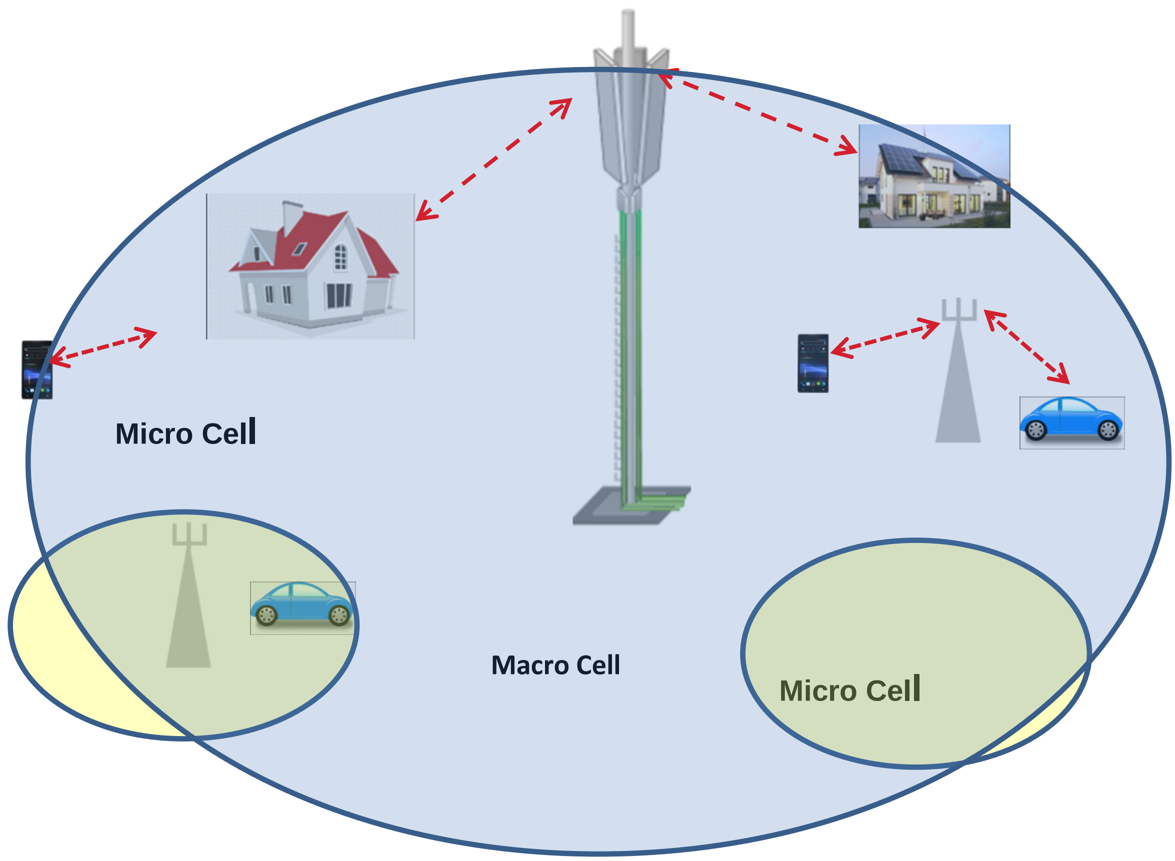


Figure 3.1 Base Station Artitechture

Multipath propagation causes interference and interference is a big problem for 3G networks due to quality of network get lower.

For instance, same problems are seen in daily routine when listening to an FM radio in the car. At radio receiver antenna the signal will become distorted. This is beacuse of two or more signals will receive to the receiver. One signal arrives to receiver from the main path and other signals are from the reflection with many different paths. Also arrival time of those signals are different because of the different paths have different lengths.

Another form of multipath propagation is known as Inter Symbol Interference (ISI). As it is shown in Figure 3.2; same signals receive different time due to reflected path lenghts are different. Receiver collects the data from all signals and combined them all. So that data may be corrupted.

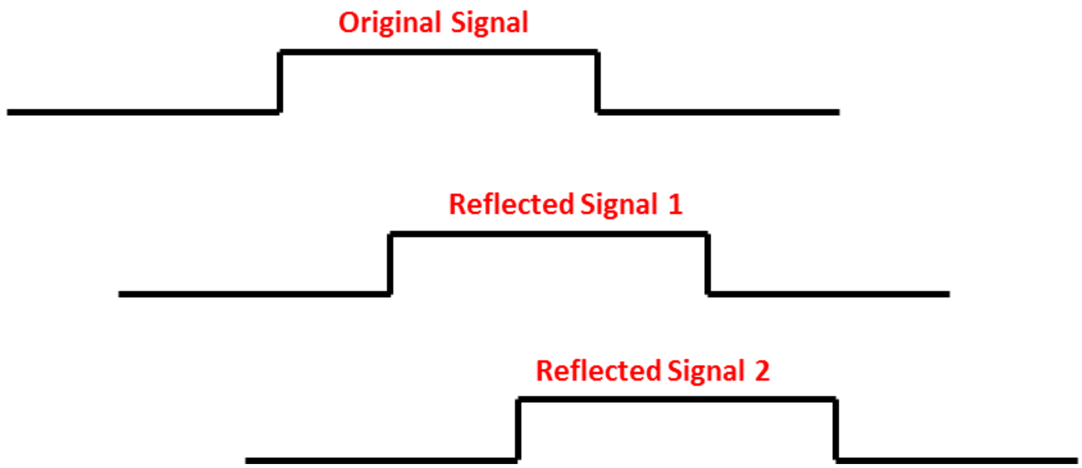


Figure3.2 Intersymbol Interference

Therefore, to minimize effects of ISI, filters are used in designing of the receiver and transmitter antennas. To prevent ISI, adaptive equalization and error correcting codes are being used.

3.2 Fast Fading

The multipath factors interfere each other. That is why different signals receive with different time and sometimes receiver cannot decode which signal is the original one. This causes frequency or signal distortion. In other words, coherence time is smaller than the period of original signal. Because phases of the received signals may be different to each other and this can eliminate all received signals so receiver cannot decode the transmitted signal.

Signal distortion is depend on Doppler spread as well.

$$p_r(r) = \begin{cases} \frac{r}{\sigma^2} e^{(-\frac{r^2}{2\sigma^2})} & r \geq 0, \\ 0 & r < 0 \end{cases} \tag{3.1}$$

In that equation, amplitudes of the signals are calculated. r is the received signal amplitude, and σ^2 is the average amplitude of all multipath signals.

The mean value of envelope E_{rec} and the variance of received signal amplitude Var_{amp}, are given in Equations below.

$$E_{rec}(r) = \sigma \cdot \sqrt[2]{\pi/2} \tag{3.2}$$

$$Var_{amp}(r) = \left(\frac{4 - \pi}{2}\right)\sigma^2 \tag{3.3}$$

In radio communication, LOS path is explained direct way between transmitter and receiver antennas.

$$p_r(r) = \frac{r}{\sigma^2} \cdot exp\left(-\frac{r^2 + r_c^2}{2\sigma^2}\right) \cdot I_o\left(\frac{rr_c}{\sigma^2}\right) \tag{3.4}$$

Where the I_o is modified Bessel function of the first kind of order zero and r_c is the dominant LOS signal component. When dominant LOS component r_c can be reduced to zero, Ricean distrubition becomes Rayleigh distribution. The Ricean K-factor is expressed as below Equation.

$$K_{Ricean}(dB) = 10log\left(\frac{r_c^2}{2\sigma^2}\right) \tag{3.5}$$

$r_c/2$ shows the power of dominant signal term. In above formula, when σ is calculated and placed in formula 3.4 then below equation is found;

$$p_r(r) = \frac{2r10^{K/10}}{r_c^2} \cdot exp\left(-\frac{10^{\frac{K}{10}}(r^2 + r_c^2)}{r_c^2}\right) \cdot I_o\left(\frac{2r10^{K/10}}{r_c}\right) \tag{3.6}$$

3.3 Slow Fading

Obstacles such as mountains, buildings or trees cause slow fading. Slow fading is a type of signal distortion as the others. Here signal distortion occurs slowly. The average level of the received signal reduces by the effect of slow fading when UE is passing through backside of a building.

$$p_r(r_s) = \frac{1}{\sqrt{2\pi\sigma}} \cdot exp\left(\frac{(r-\mu)}{2\sigma^2}\right) \tag{3.7}$$

Where r_s is received slow fading signal, u is mean deviation and σ is standard deviation. The standart deviation of slow fading depends on the obstacles and used frequency type.

3.4 Delay Spread

Due to different lenghts of the multi paths, signals receive at different times to receiver antenna. That causes a delay between the arrival of first signal and last signal to receiver. So receiver cannot decode if the last signal is a reflected signal or a new signal.

Delay spread is shown with S_d and the channel power delay profile is $P_{(t)}$ so the formula is as (3.8).

$$S_d = \sqrt{\frac{\int_0^{\infty}(\tau - D)^2 P_{(\tau)} d\tau}{\int_0^{\infty} P_{(\tau)} d\tau}} \tag{3.8}$$

D is average delay. Delay spread vary on with the obstacles, where the wave propagates. As explained above delay is defined as difference of time between the arrival of first signal and last signal to receiver.

3.5 Angular Spread

As explained above, different signals may receive with different angles to receiver. When the receiver sum up all signals with different angles, some signals eliminate each other because of the angles are totally reverse. Below formula is used to calculate, angular spread $S\varphi$:

$$S_{\emptyset} = \sqrt{\int_{\Phi-180}^{\Phi+180} (\Phi - \overline{\Phi})^2 \cdot \frac{P_{ang}(\Phi)}{P_{\Phi\_tot}} d\Phi} \tag{3.9}$$

In above $\overline{\Phi}$ is the average angle, $P_{ang}(\varphi)$ is angular power distribution, and P_{Φ_tot} is the total angular received power.

3.6 Coherence Bandwidth

Lacki [1, p. 40] explained coherence bandwidth as:

"The bandwidth, over which two frequencies of a signal experience the same fading characteristics, is called coherence bandwidth. The coherence bandwidth Δfc is calculated as a function of multipath delay spread S_d. It is defined in the following equation.

$$\Delta f_c = \frac{1}{2\pi S_d} \tag{3.10}$$

Where S_d is the delay spread. The coherence bandwidth varies, depending on the multipath delay spread. To avoid correlated fading of two signals, the frequency separation between them should equal or be higher than coherence bandwidth."

3.7 Propagation Slope

The propagation slope tells how much the signal attenuation is and it depends on environment. Signal attenuation ocur different in a city with high buildings comparable with a desert. In the city centers signal fading is high due to obstacles absort signals But in a desert signal is faded by ground or sand. As expected, distance between receiver and a transmitter play a big role for free space propagation. That slope equals square of the distance. The distance, where the propagation slope changes over network coverage area is called breakpoint distance B. This can be calculated using the following equation.

$$B = 4\frac{h_{BTS} \cdot h_{MS}}{\lambda} \tag{3.11}$$

So above formula, $\mathrm{h_{BTS}}$ is the base station effective antenna height because it can be on a flat or building or a tower. $\mathrm{h_{MS}}$ is the UE antenna height as maximum user person's height. Generally beginning of the network planning $\mathrm{h_{MS}}$ is taken as 2 meters.

4. SOFT HANDOVER PERFORMANCES AND ALGORITHM

Soft Handover (SHO) performances, how SHO algorithm works, SHO overhead and SHO events are described in this chapter. Our measurement aim is to monitor SHO changes with active set size parameter, and effect on HSUPA throughput. Active set size window can be limited from the RNC by setting one parameter and so on UE can add or remove radio links if the SHO algorithm is available, it can add some cells to active set. As opposite, even if AS size parameter is set to four, if some cell signals are below the threshold, UE removes those cells from the AS window. In this thesis those thresholds and triggering parameters will be explained.

4.1 SHO Performances

4.1.1 SHO procedure and algorithm

Soft and softer handover are explained above chapters. Algorithms behind SHO calculation methods are described in 3GPP specification. In the DL direction, when UE receives signals from the two or more different NodeBs, signals are combined. But in the uplink direction, received signals cannot be combined due to NodeBs are different. So UL signals are routed to the RNC. As the outer loop power control algorithm measures the SNR of received uplink signals at a rate between 10 and 100Hz, this information is used to select the frame with the best quality during the soft handover. In this thesis focus point is AS size changes, the number of cells the UE has radio link connections at the same time.

4.1.2 Measurements

E_c/N_o measurements of the Common Pilot Channel (CPICH) are the main input for UEs to make handovers. Mainly three parameters can be measured. Besides the E_c/N_o also the received signal code power (RSCP) and the received signal strength indicator (RSSI) are measured. RSCP is the power carried by the decoded pilot channel and RSSI is the total wideband received power within the channel bandwidth. $\frac{E_c}{N_0}$ is defined as:

$$\frac{\mathrm{E_c}}{\mathrm{N_0}} = \frac{RSCP}{RSSI} \tag{4.1}$$

It is important to apply filtering on the handover measurements to average out the effect of fast fading. Measurement errors can lead to unnecessary handovers or dropped calls. If operators use big algorithm parameters that may cause delays in the handovers. Using small HO parameters may cause ping pong handovers. Also the speed of the UE is important to decode right candidate cells.

4.1.3 The soft handover algorithm

Based on the E_c/I_o measurements of the set of cells monitored, the mobile station decides which of three basic actions to perform; it is possible to add, remove or replace a NodeB in the active set. These tasks are respectively called radio link addition and radio link removal or radio link replacement. Discussing this scenario gives a good insight into the algorithm itself. Active set size parameter changes will effect the RL addition/removal and replacement counts and will be shared on measurement results.

The most important action is for the UE, to add/remove/replace the right candidate cells. If UE make a wrong cell selective that can cause drop call or low throughput problems. Figure 4.1 shows how cells are added or removed on Active Set according to serving areas of the different cells.

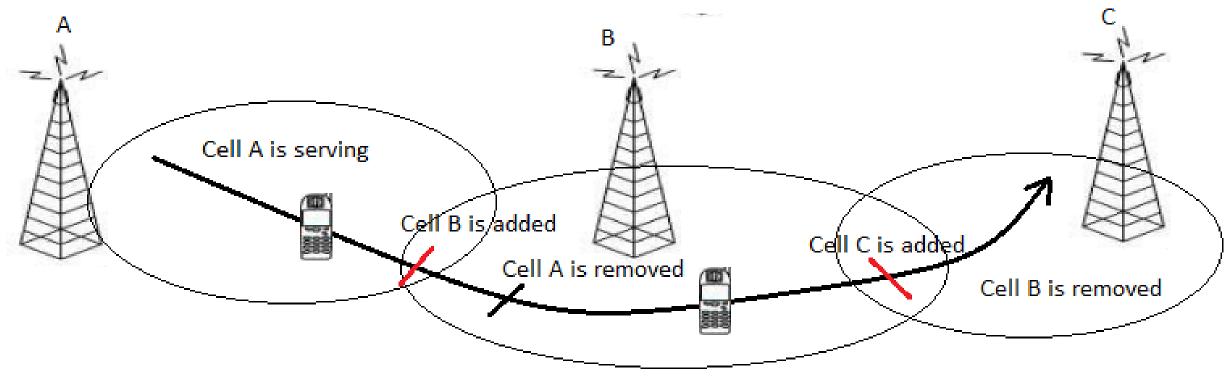


Figure 4.1 SHO Scenario

When the measurement values satisfy the following formulas, the UE deems that a primary pilot channel has entered the reporting range:

Path Loss:

$$10\log M_{new} < W \times 10\log(\sum_{j=1}^{N_a} M_i) + (1-W) \times 10\log M_{Best} + \left(R - \frac{H1A}{2}\right) \tag{4.2}$$

where, M_{new} is the measurement result of the cell that has entered the reporting range, M_i is the measurement result of the cells in the active set, N_a is the number of cells in the current active set, M_{Best} is the measurement result of the best cell in the current active set, W is the weight factor, R is the reporting range, H1A is the hysteresis value of event 1A. With the signal strength as an example, R equals to the signal strength of the best cell in the current active set minus a value

Figure 4.2 explains the handover algorithm working conditions. Each event means one active set change. UE makes the measurements of CPICH power for the neighboring cells and if the condition is suitable Events can be seen on the measurements.

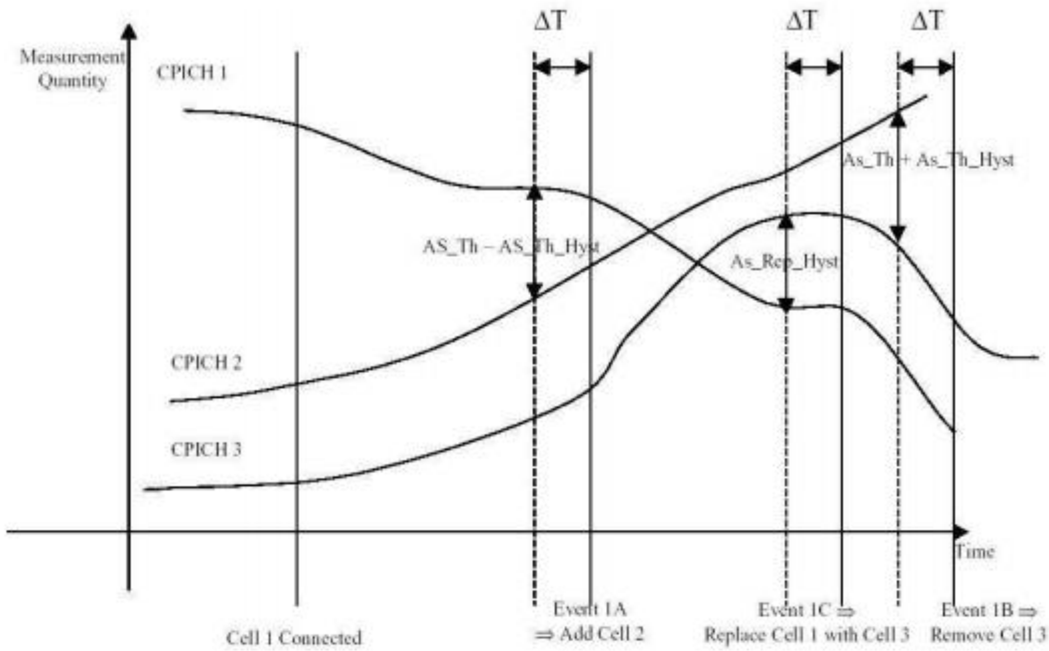


Figure 4.2 WCDMA Handover Algorithm

Active set, monitored set and detected set are very important to monitor network quality. These three set will be defined as below:

• Active set includes cells that are serving to UE or in other words the cells that are in soft or softer handover connection.

• Monitored set shows cells, which cells are neighbour with the cells in AS and RSRP or E_c/N_o values are not good enough to be added to the active set,

• Detected set includes cells, that are not neighbour to the AS cells. Detected cells pilot-channels power can be high enough (must defined neighbour) or not. [4]

Below events are important for SHO algorithm and each one has an explanation as shown below for Figure 4.2:

- Event 1A: add cell 2 to active set

- Event 1B: Cell 3 is removed from the active set becasue its measurement result is below of the threshold.

- Event 1C: cell 1 measurement results are good for a certain time and it is replaced with cell 3.

4.1.4 Softer handover and soft handover algorithms

Presently, RNC V1.2 uses two soft handover algorithms:

- Loose-mode algorithm
- Relative threshold algorithm

Loose-mode Algorithm: When either event1A or event1E is satisfied, it will be deemed as the trigger condition for adding a softhandover branch;

After event1A or 1E is received, if the number of cells in the active set is 3, no processing will be implemented.

When neither the relative threshold nor the absolute threshold (event1B and 1F) is satisfied, it is deemed as the trigger condition for removing a soft handover branch. If handover is triggered when either event1B or 1F is received, but the triggered cell is the best cell, then no processing will be made. Event1C is the trigger condition for cell replacement in the active set.

Event1D occurs in the active set cell and measurement control changes, based on the best cell operation algorithm. Event1D occurs in the monitored set cell and this cell is added into the active set. İf the active set is full, remove any cell among nonbest cells and then add the reported best cell and mark it as the best cell. After successful operation, the measurement control process is started.

Qinyan[5, p. 17] explained Relative Threshold Algorithm as:

"When event 1A report is received, if the active set is not full, then links are sequenced and added in the order of good quality to poor quality (CPICH E_c/N_o) until the active set is full; if the active set is already full, no processing will be made. When Event 1B is received, if there are more than one links in the active set, then the braches are sequenced and removed in the order of poor quality (CPICH E_c/N_o) until only one link is left; if there is only one in the active set, no processing will be made.

In case of Event 1C, the UE will report the replacing and replaced cells in the event trigger list. İf the active set is not full, then the triggered cell link will be added; if the active set is already full at this moment and the replaced cell is not the best cell in the active set, then this cell link will be removed.

In cade of event 1D, if the triggered cell is an active set cell, then it will be marked as the best cell and measurement control is updated; if the triggered cell does not belong to the active set, then this cell link will be added and marked as the best cell, with measurement control updated."

4.1.5 SHO overhead

As explained many times in this thesis, capacity and coverage are two main part of the WCDMA systems. SHO system performance can be expressed by the unseccessful SHO rates, call blocking and undefined neighbor relations. In WCDMA networks, downlink capacity is very important. Soft handover may provide capacity. Soft handover's aim is to decrease interference by reducing NodeB power. If there are three cells in active set and UE sends a message to best serving cell as "power down" then other two cells will decrease their power. After reducing power one cell is not good enough, UE will remove that radio link and decreases active set size from 3 to 2.

The SHO is a feature in WCDMA systems. SHO gain provides an additional gain against slow fading and reduces radio link loss due to multiple handovers. SHO using aim is to find the best serving cells with lower transmission power. E_c/N_o or RSCP values can be selected as comparision criteria of downlink CPICH. As explained above many times, WCDMA systems are interference limited so that task of SHO design is planned to choose the cell with good QoS.

The SHO overhead can be changed by SHO parameters, which change the SHO probability. This Master Thesis's aim is to find best active set size for the higher uplink throughputs.

Soft Handover Overhead (SHO) is calculated by below formula (4.4). In a GSM network the soft handover is not exist so SHO overhead is always 0%. The soft handover overhead is a measurement on how many connections on average exceeding a mobile has got to the network. A large soft handover overhead indicates that each mobile has got many connections on average to the network (>1) > Average AS size is high. A low soft handover overhead indicates that each mobile has got few connections on average to the network (~1) > Average AS size is low. A large SHO could indicate that too many resources are used by the mobile. A low SHO could indicate that there could be more gain achieved in having several connections to the network and that the mobile does use too much transmit power on average. A well balanced SHO is about 30-40% .

$$\text{SHO\_Overhead}(\%) = 100 \times \frac{Number\ of\ active\ RL\ in\ the\ network}{Number\ of\ UEs\ with\ AS > 0} - 1 \qquad (4.4)$$

SHO overhead measurements are showed in Figure 4.3. This measurement is taken from OPTIMA tool. As it can be seen when active set size parameter is changed to 4, SHO overhead increased as expected because UEs started to include 4th candidate cell for the suitable locations.

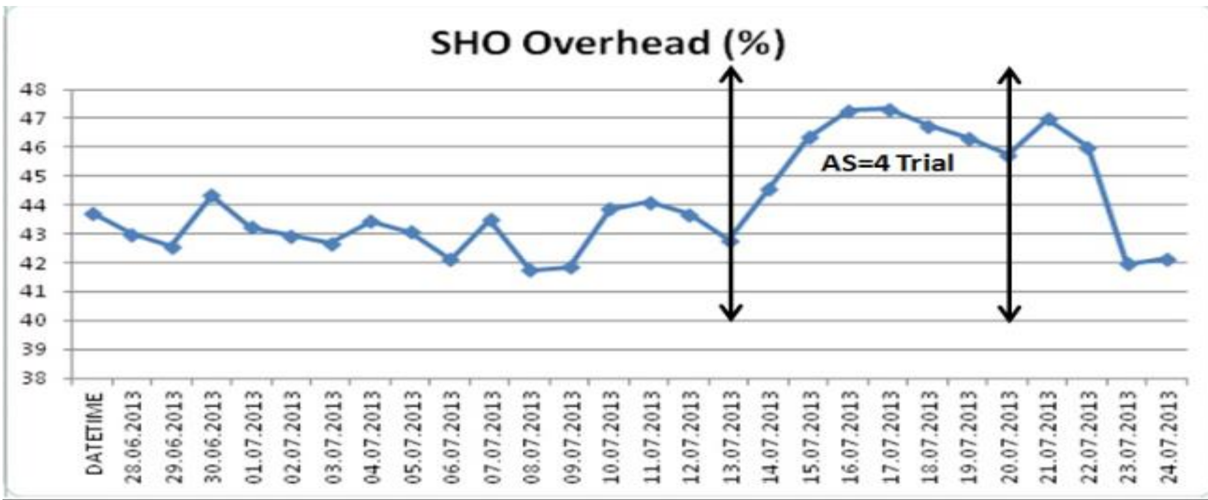


Figure 4.3 SHO Overhead for AS3 and AS4

5. DRIVE TEST MEASUREMENTS AND SETUP

5.1 Measurement

These drive test measurements were completed to find out the soft handover behaviors, speech and data quality changes with different active set sizes in 3G. The drive test was done by TEMS (Test Mobile System) Investigation. Cell phones were used for speech measurements and Huawei data modem was used for data measurements

There different drive tests were conducted with different active set sizes. Test equipment, veichle route and CPICH power for NodeB were kept the same throughtout all mesurements to see directly effect of active set size changes. Base station parameters for the measurement are shown in Table 5.1.

Table 5.1 Measurement Parameters of NodeBs

	Parameter	Value
Base Station	Maximummm Transmission Power	42.6 dBm
	Common Pilot Channel (CPICH)	340 dBm
	Other Common Channels (CCCH)	240 dBm
	Synchronization Channel (SCH)	240 dBm
	Antenna Types	K742265&K742215
	BandWidth	5 MHz

In Figure 5.1 GPS, phones, data Card and USB cables for TEMS are shown.

Figure 5.1 Equipment for Drive Test

A Test tool is used for reading and controling information sent over the air interface between the NodeB and the UE in WCDMA cellular system. TEMS Investigation is very commonly used tool in the telecom market for troubleshooting. Many operators use TEMS to monitor their network quality and measure customer satisfaction.

Figure 5.2 shows the equipment list which was used during test. Inside the vehicle laptop is installed and connected to data card in order to measure QoS parameters. Also, GPS is used to define the exact location. GPS collects the samples and TEMS combines all data information between UE and NodeB. Dongle is needed for TEMS, without a licensed dongle it is impossible to run TEMS. Inverter is used for laptop battery charge in the car during test because test takes 6 hours.

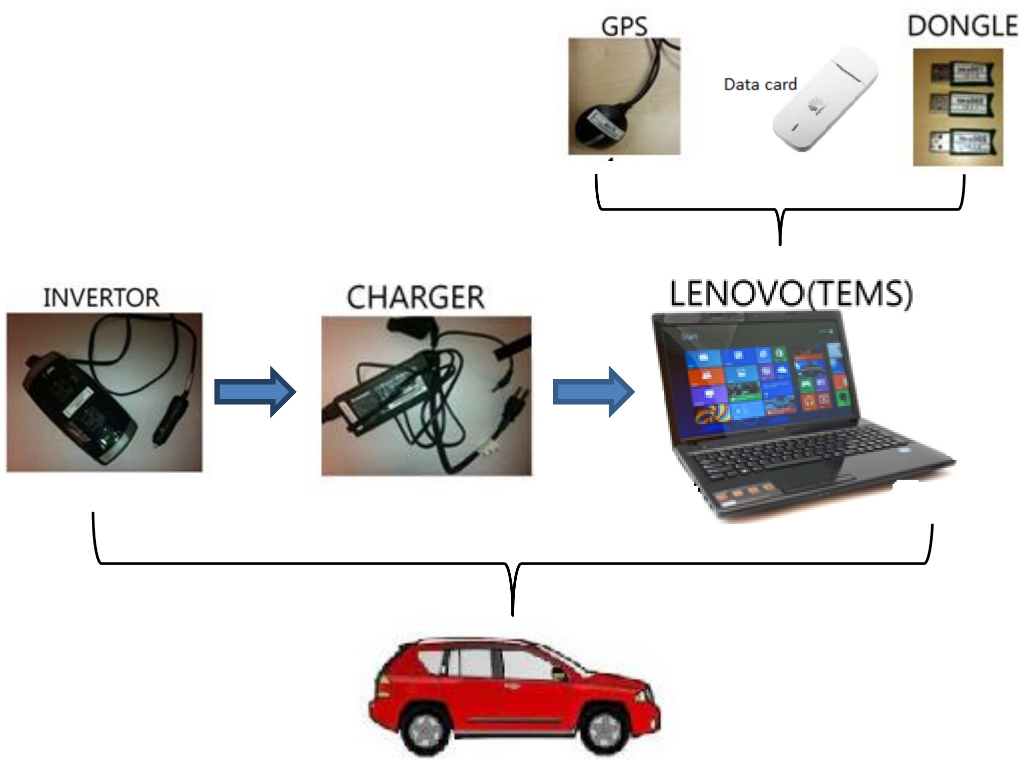


Figure 5.2 Equipment List

5.2 Measurement Details

As explained in the thesis, AS size is being used 3 by default for operators. Default handover parameters are set to same values for different AS size trials. As shown Table 5.2, MAXCELLINACTIVESET parameter changed from 3 to 4 and 2.

Table 5.2 SHO and AS Parameters

SHO Parameters	Parameter description	Default	Set-1	Set-2
Trigtime1A	Event 1A Triggering Delay	100 ms	100 ms	100 ms
Trigtime1B	Event 1B Triggering Delay	2560 ms	2560 ms	2560 ms
Trigtime1C	Event 1C Triggering Delay	640 ms	640 ms	640 ms
Maxcellinactiveset	Active set count	3	4	2

Event1 parameters are kept same during the tests to see the exact effect of maxcellinacttiveset parameter.

5.3 Measurement Results

5.3.1 Trial for active set equal to 4

MAXCELLINACTIVESET parameter is set to 4. As explained above, operators don't use maxcellinactiveset = 1 because WCDMA systems enables SHO. So that this parameter is set to 2 as minimum. Figure 5.3 shows the AS distrubition on the route. In the legend it is seen, the sample counts and sample percentage. 11,30% of the route is being served by 4 cells in the active set. By setting the AS as 4, UEs is able to connect with up to 4 cells at the same time. But as it is seen, UE connected 4 cells at only 11,3% of total route of test. In the test, only one UE (data card) was used. This shows us if conditions are not completed for UE, AS size can not seen as 4 through test route. For some routes, UE is only connected to 2 or 3 cells due to SHO algorithm doesn't let other cells to enter AS.

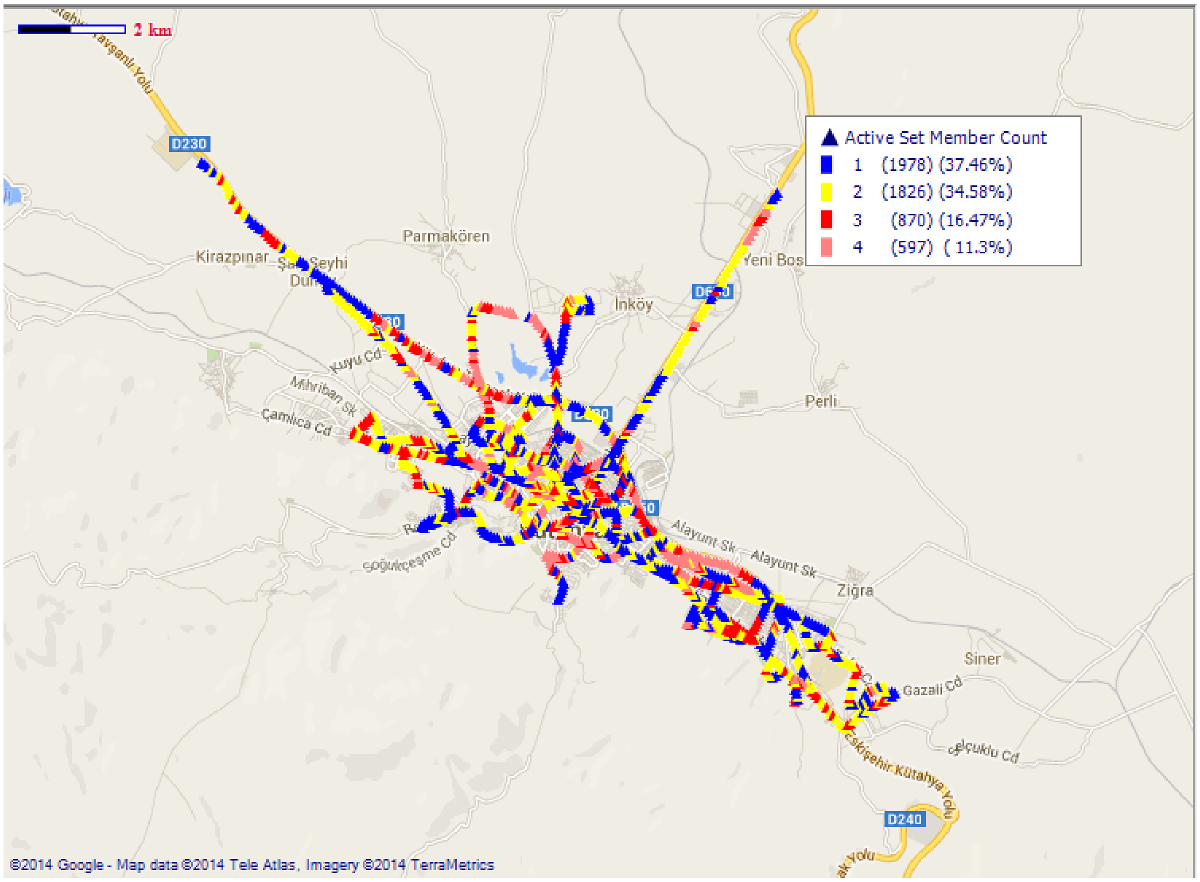


Figure 5.3 Active Set Member Count (AS=4)

In Figure 5.4 for AS=4, E_c/I_o measurements are given which shows the quality. Normally E_c/I_o is measured in a range between -30 dB to 0 dB and higher E_c/I_o shows better network quality. Till E_c/I_o is -11dB, it is acceptable. Values below -11 dB show the network quality problems. For AS=4, unacceptable quality sample is measured as 5,42% that is sum of 1,39% and 4,13% as explained bad samples. These values are on the legend. E_c/I_o average is measured as -6,93 dB.

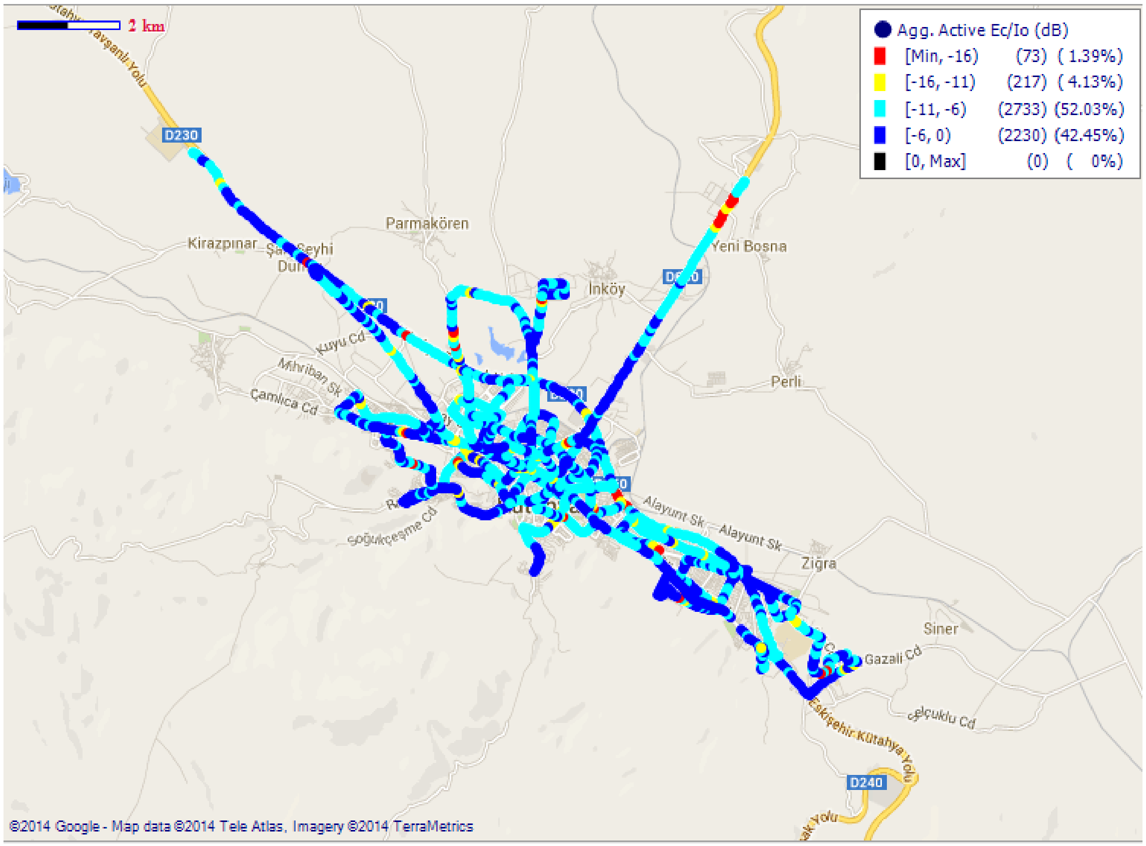


Figure 5.4 Ec/I$_o$ Distrubition with AS=4

Figure 5.5 shows HO statistics or as explained before SHO attemps. When the UE added a new link to AS, “RL Addition” counter increases. So when parameter is set to AS=4, UE made more RL additions and Removals as expected. RL (Radio Link) Addition count is 544, RL Removal is 462. RL addition number is higher than the AS3 and AS2 trials. RL Removal count is higher than AS2 trial but less than AS3 trial. Reason of that is, more cells are being let to stay in AS during this trial so less RL removal is seen as expected.

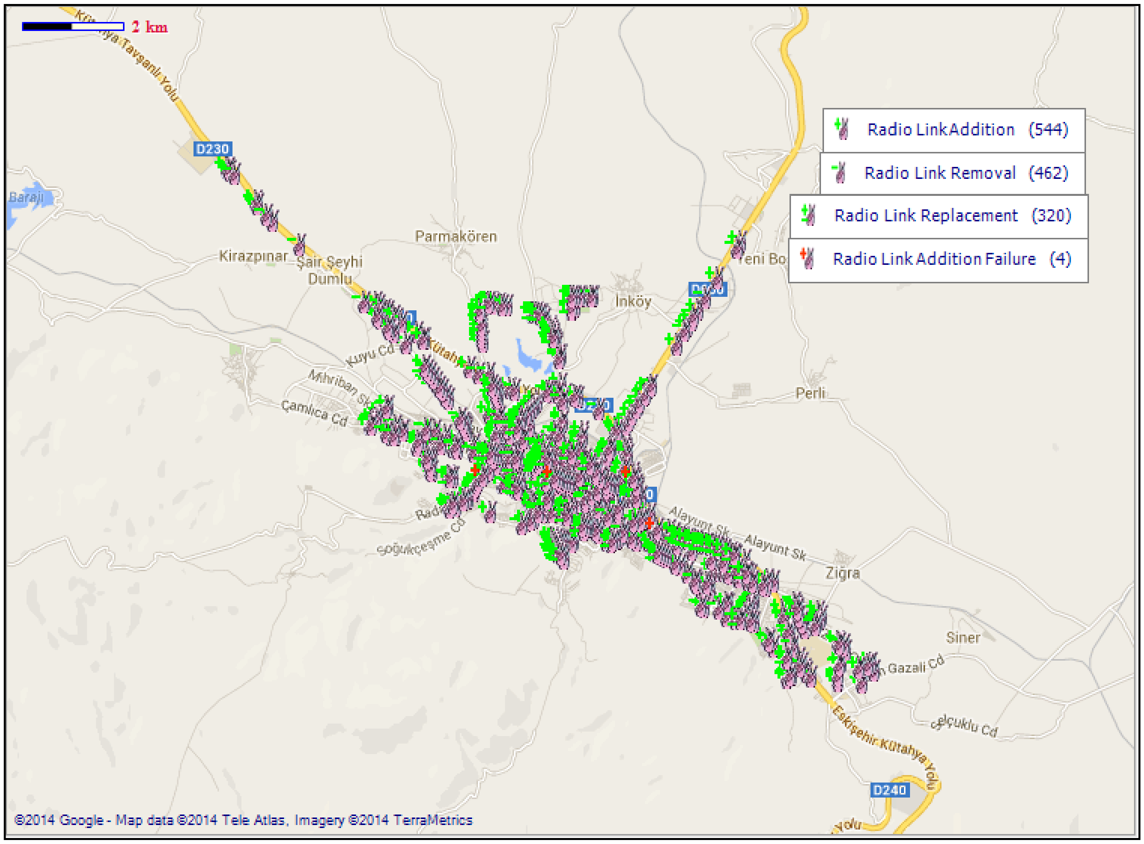


Figure 5.5 Speech Call Events(AS=4)

UL test is done by using an ftp site and uploading a file around 1GB to this ftp site. When the upload has finished, it started to upload same file again thus all route is completed by uploading same file without interruption. Throughput shows us the speed of uplink. HSUPA UL average is measured 1579 kbps and samples higher than 5 Mbps percentage is 9,41% for AS=4 as shown in Figure 5.6.

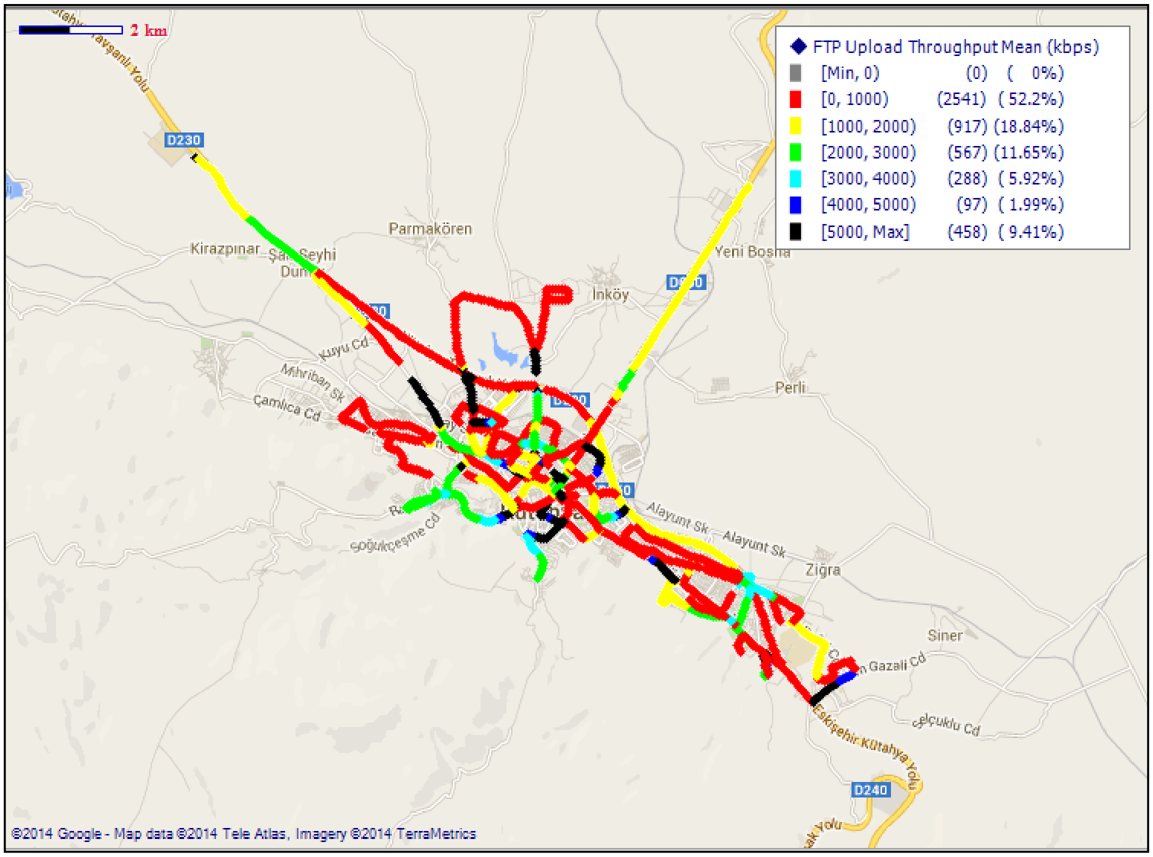


Figure 5.6 FTP Upload Tput(AS=4)

5.3.2 Trial for active set equal to 2

MAXCELLINACTIVESET parameter is set to 2. Figure 5.7 shows the AS distrubition on the route. 38,92% of the route is being served 2 cells in the Active Set. As seen on the Figure 5.7, there is no samples for AS3 and AS4 size measurements.

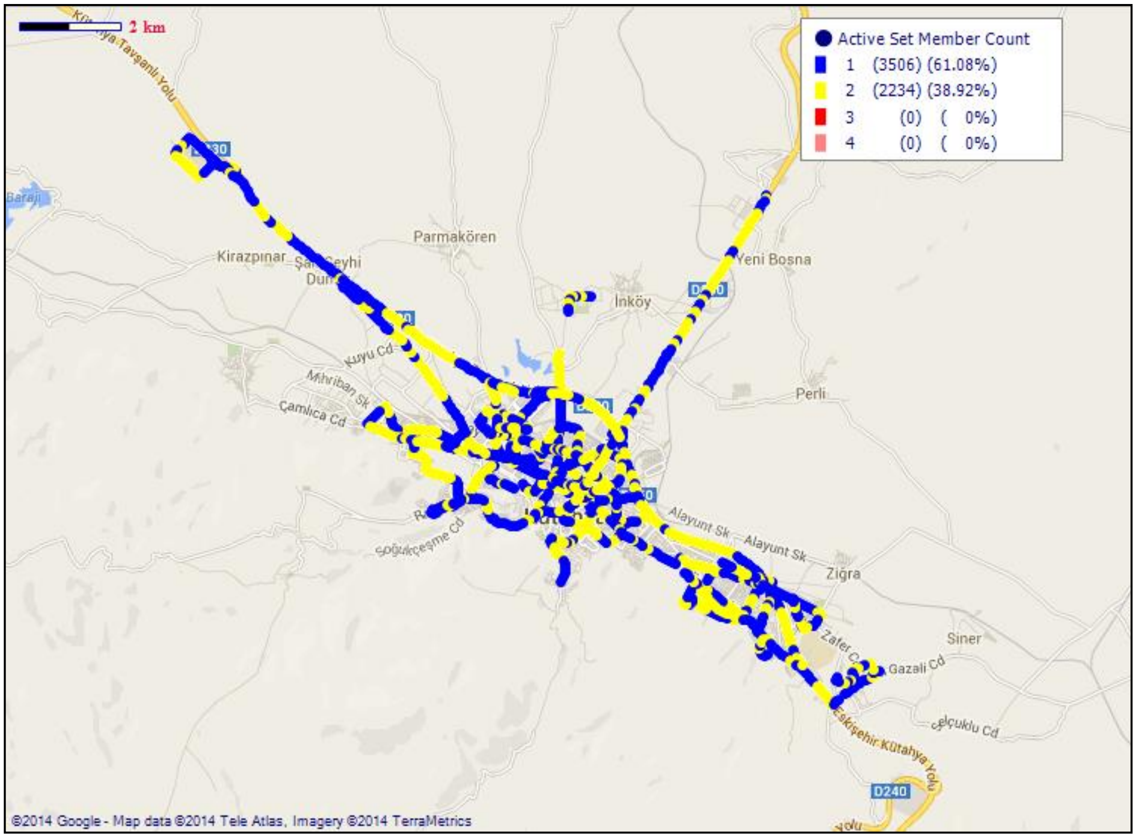


Figure 5.7 AS Member Count for Speech(AS=2)

After “maxactiveset” parameter is set to 2, 61,08% of the samples are with one radio link as shown in Figure 5.7. The negative situation of that case is, due to UE couldn’t add new cells to AS when it was 2, other cells may increase the interference and effect quality negatively.

Unacceptable E_c/I_o percentage is 4,81% but E_c/I_o average is measured -6,84 dB for AS=2. As shown in Figure.5.8, quality is measured better than AS=4 trial and that shows us if the neighboor definitions are done well, AS=2 doesn’t decrease the quality.

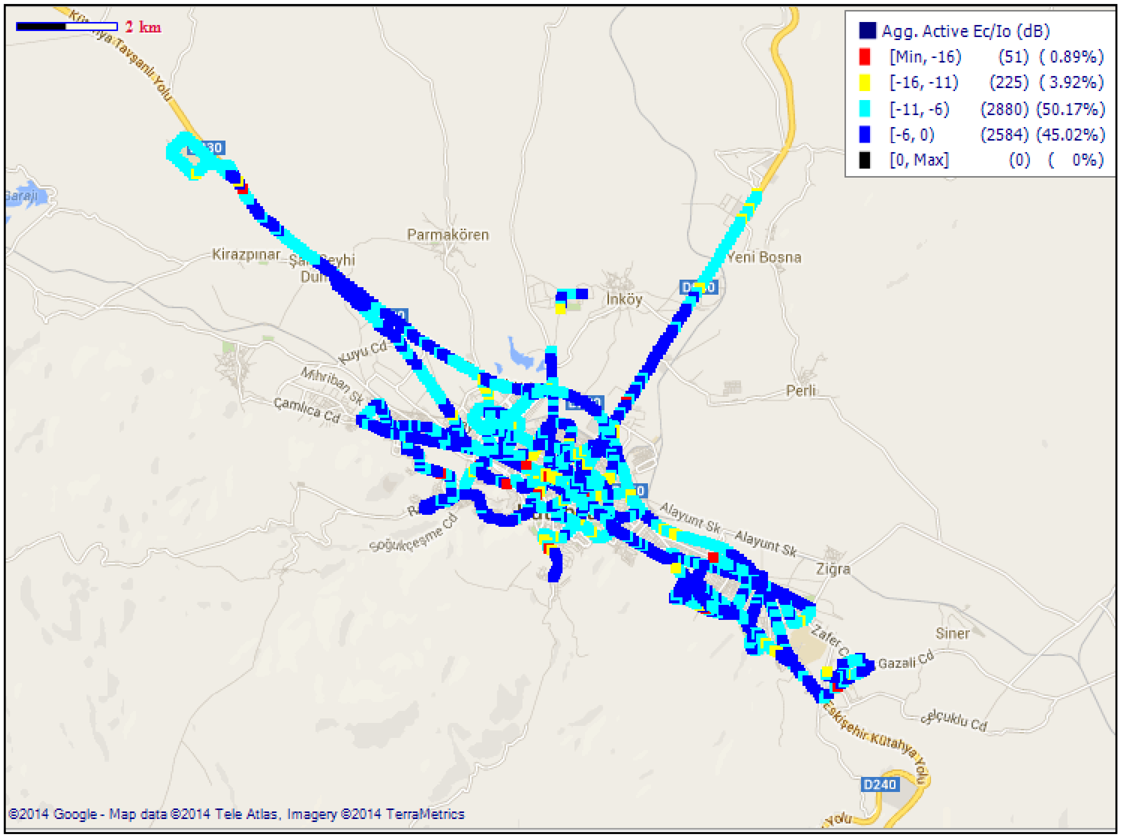


Figure 5.8 E_c/I_o Distrubition(AS=2)

Figure 5.9 shows HO statistics. RL(Radio Link) Addition count is 246, RL Removal is 188. RL Replacement count is increased almost double according to AS=4 trial. This is because of the UE replaced better measured cells with serving cells during the test. When AS size is decreased from 4 to 2, RL Addition and Removal counts decreased but RL Replacement counts increased as expected. Reason of that; UE makes replacements instead of adding new cell to AS.

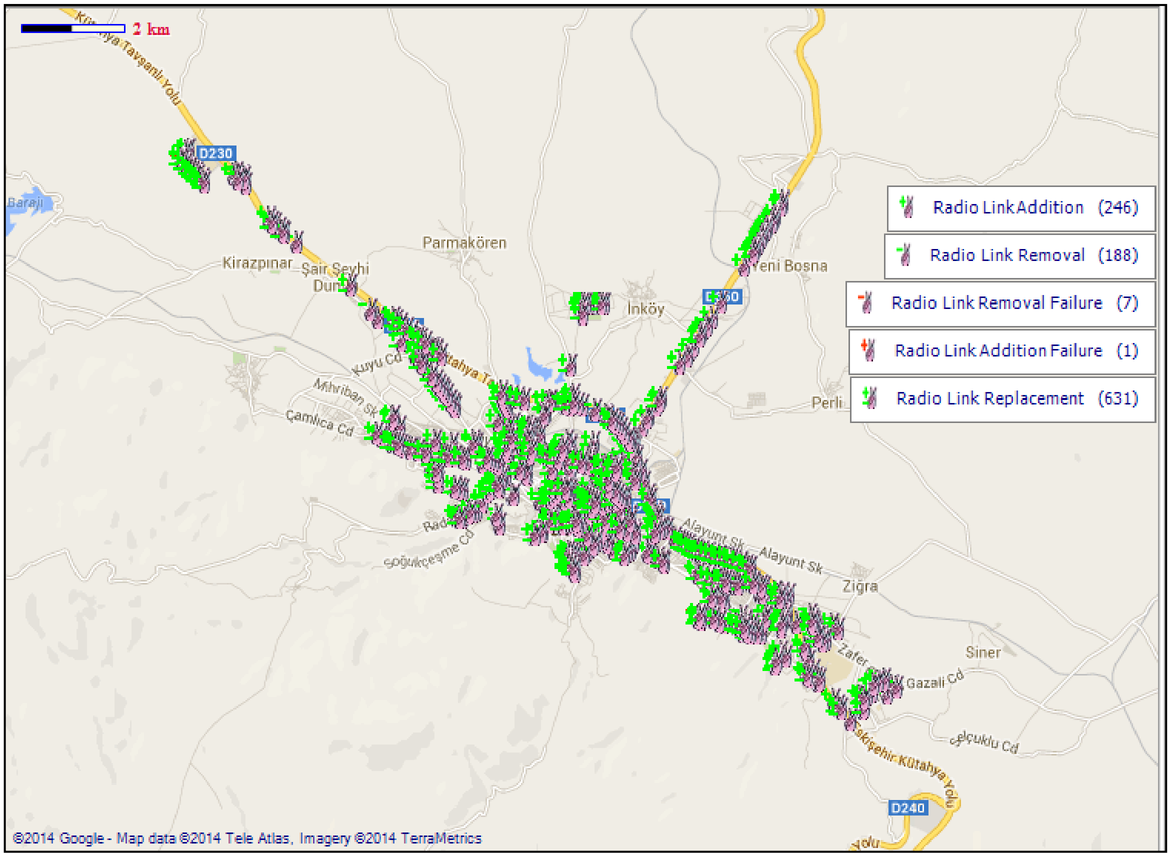


Figure 5.9 Speech Call Events(AS=2)

HSUPA Throughput average is measured 2034.70 kbps and samples higher than 5Mbps is 5,44% for AS=2. HSUPA Throughput average is increased compared to AS 4 trial. One reason of that is good network quality, Ec/Io. Distrubition of the HSUPA samples are shown in Fig. 5.10 for AS=2 trial.

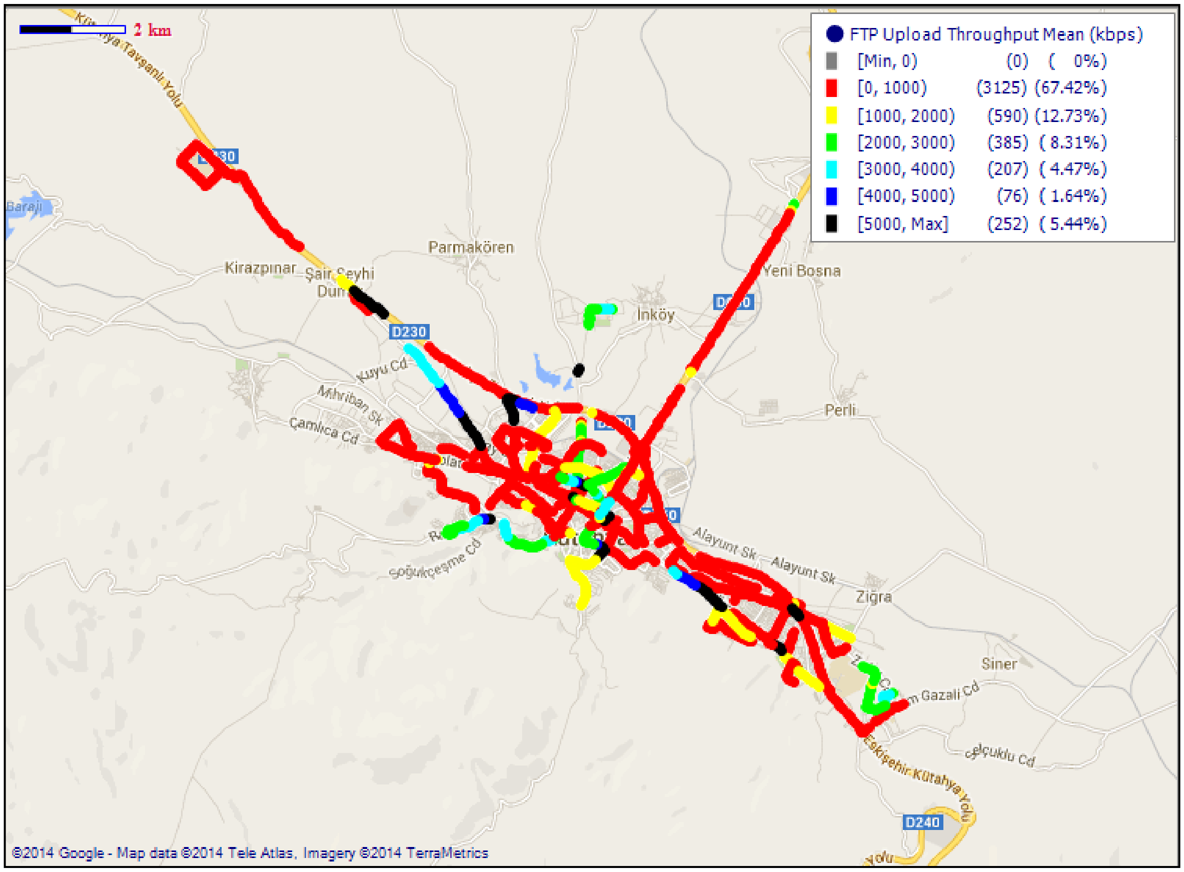


Figure 5.10 FTP Upload Tput(AS=2)

5.3.3 Trial for active set equal to 3

MAXCELLINACTIVESET parameter is set to 3. Figure 5.11 shows the AS distrubition on the route. 25,32 % of the route is being served 3 cells in the Active Set.

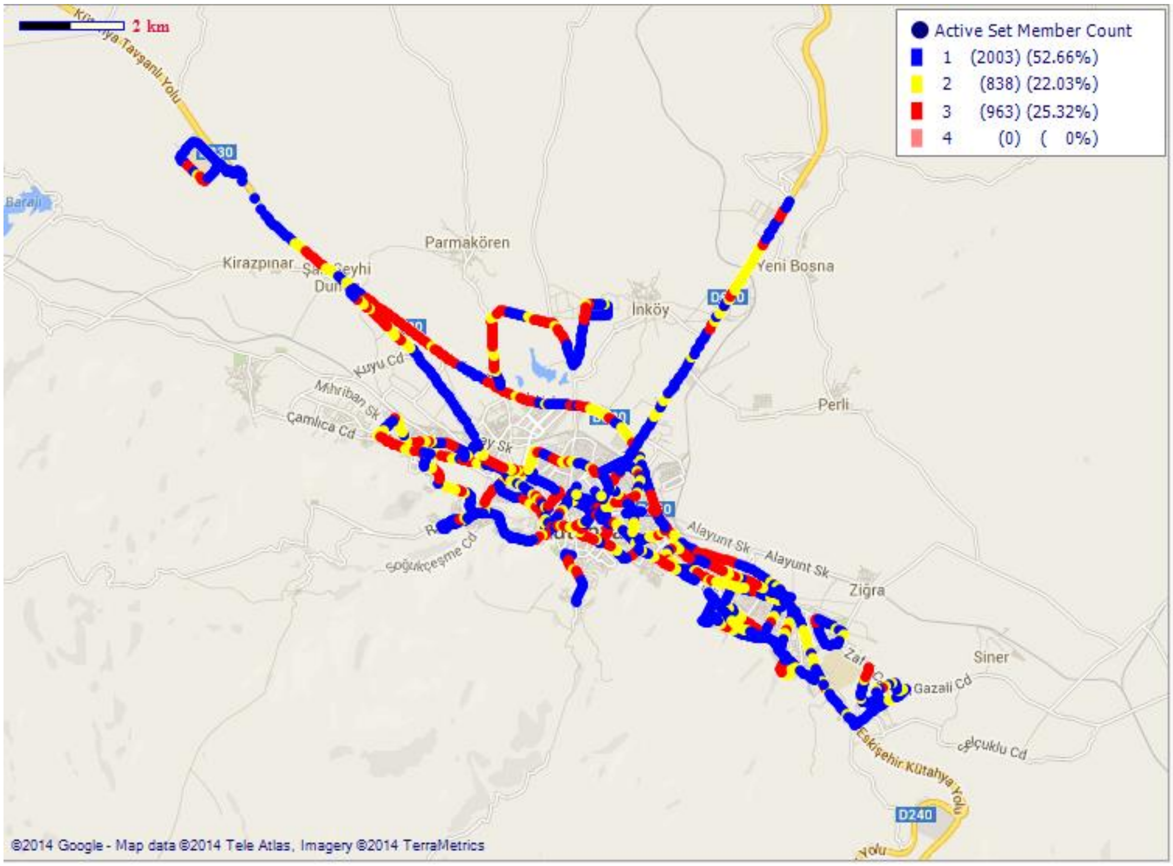


Figure 5.11 AS Member Count for Data Test Speech (AS=3)

Unacceptable E_c/I_o percentage is 4,86%. E_c/I_o average is -6,25 dB. This average is the best one comparing to other two trials. Distrubition of samples shown in Figure 5.12

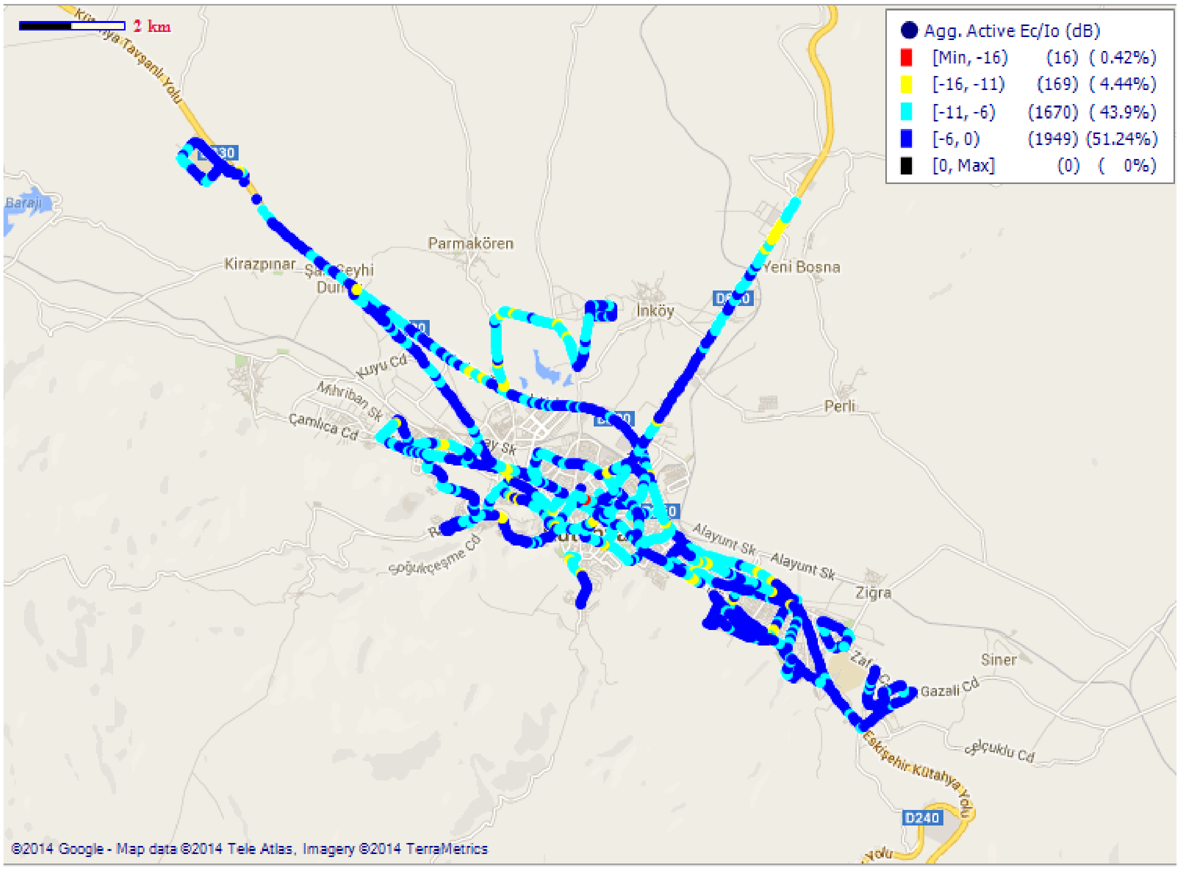


Figure 5.12 E_c/I_o Distrubition(AS=3)

Figure 5.13 shows HO statistics for AS=3 trial. RL (Radio Link) Addition count is 517, RL Removal is 502. Totally 8 RL fails are occured during the test.

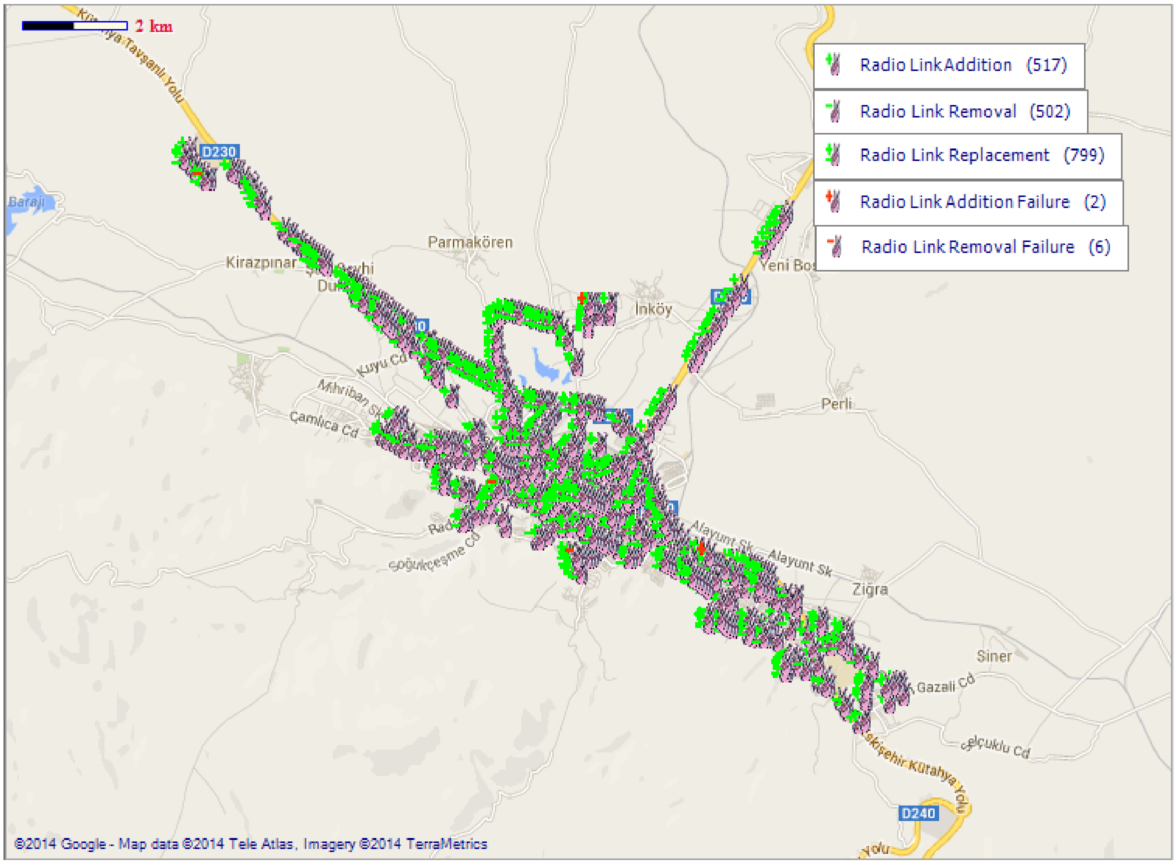


Figure 5.13 Speech Call Events. (AS=3).

HSUPA Throughput average is measured 1781,10 kbps and samples higher than 5Mbps is 16,30% for AS=3. Altough E_c/I_o is beter than other trials, HSUPA T'put is lower than the AS 2 trial. This shows us only E_c/I_o is not enough for best uplink throughput. Figure 5.14 shows distrubition of samples.

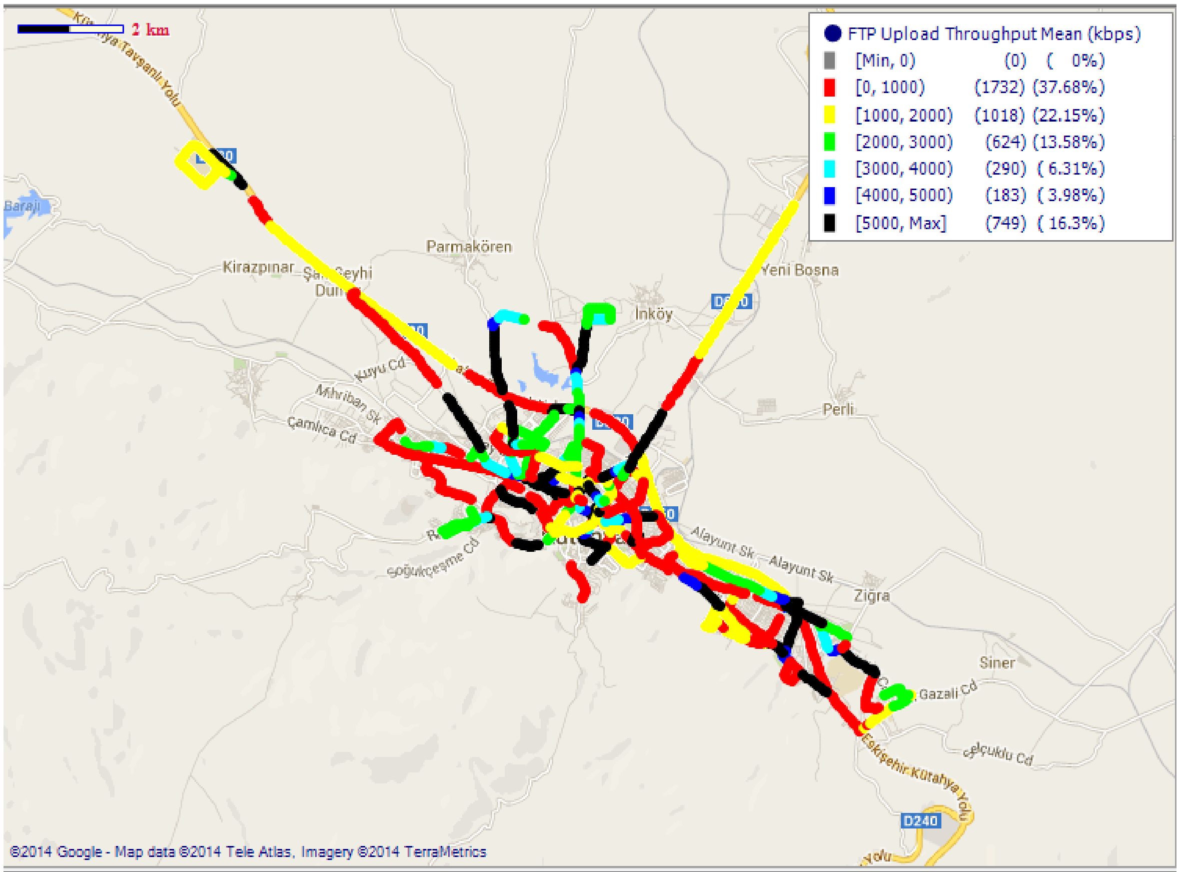


Figure 5.14 FTP Upload Tput(AS=3)

5.4 Comparision of Trials for Active Set

The signal-to-interference power ratio, denoted SIR, is measured almost same for each trial. But for AS=2 trials gave us better SIR values ranges between 15-20. Table 5.3 shows distrubition of SIR values for each test.

Table 5.3 SIR Values

SIR Distrubition	0-5 (%)	5-10 (%)	10-15 (%)	15-20 (%)
AS-2	0,02	18,49	56,22	23,05
AS-3	0,02	19,57	57,26	21,29
AS-4	0,08	17,59	59,7	21,32

2ms transmission time interval (TTI) allows for a very short latency in the uplink packet data transmission. Uplink data transfer speed (UL Througput) are being measured, so in WCDMA systems, uplink data is carried by Dedicated Physical Data Channel (E-DPDCH), Multi-code and high order modulation scheme are employed to increase the peak data rate. The transmission time Interval (TTI) for this channel could be 2ms or 10ms. Contiguous TTIs are divided into a number of H-ARQ processes (8 processes for 2ms TTI and 4 processes for 10ms TTI). Bigger 2ms TTI percentage gives us higher UL throughput. From the measurements, Table 5.4 shows us higher 2ms TTI belongs to AS=2 trial. When AS4 is set, 10ms TTI is increased because UE is connected more cells at the same time and this affects capacity of the NodeBs and so that NodeBs apply some load controls and lower the data speed. In AS2 trial, due to UE is connected less cells, NodeBs doesn’t apply any load control and 2ms TTI usage is higher.

Table 5.4 HSUPA TTI Percentage

EUL TTI	2ms (%)	10ms (%)
AS-2	93,24	6,76
AS-3	91,38	8,62
AS-4	75,61	24,39

Uplink throughput distrubition is seen Table 5.5. This table shows us the samples of percentage for each interval. AS-3 trial has the best samples for higher than 5 Mbps but also between 1000-2000 kbps samples are also very high for the same test.

Table 5.5 UL Tput Percentage Distribution

HSUPA Throughput Distrubition (%)	0-1000 (kbps)	1000-2000 (kbps)	2000-3000 (kbps)	3000-4000 (kbps)	4000-5000 (kbps)	5000-Max (kbps)
AS-2	67,42	12,73	8,31	4,47	1,64	5,44
AS-3	37,68	22,15	13,58	6,31	3,98	16,3
AS-4	52,2	18,84	11,65	5,92	1,99	9,41

Because of that, best average throughput is measured for AS-2 trial as shown below Table 5.6.

Table 5.6 Average Tput for Each

Trials	HSUPA Avg Throughput (kbps)
AS-2	2034
AS-3	1781
AS-4	1579

As mentioned above, best HSUPA average throughput is measured for AS=2 trial. This is the average of all samples during test. Reason of that is 2ms TTI usage is higher for AS2 trial than the other trials. AS2 average HSUPA is 14% higher than AS3 trial and 28% higher than AS4 trial.

5.5 Simulation of SHO for Each Measurement

As it is seen by measurement results, when AS=4 was set, the interference levels reduce due to UE connected one more cell which was interferer before. But at the same time UL Tput reduced due to 2ms TTI percenage is low. Because when UE uses more radio links on the uplink, Node B’s (base stations) uses more resources and 2ms TTI usage decreases and that directly effects UL speed.

For AS=2 trial measurements, interference ratio increased because one more cell started to become as interferer. But UL throughput increased at the same time.

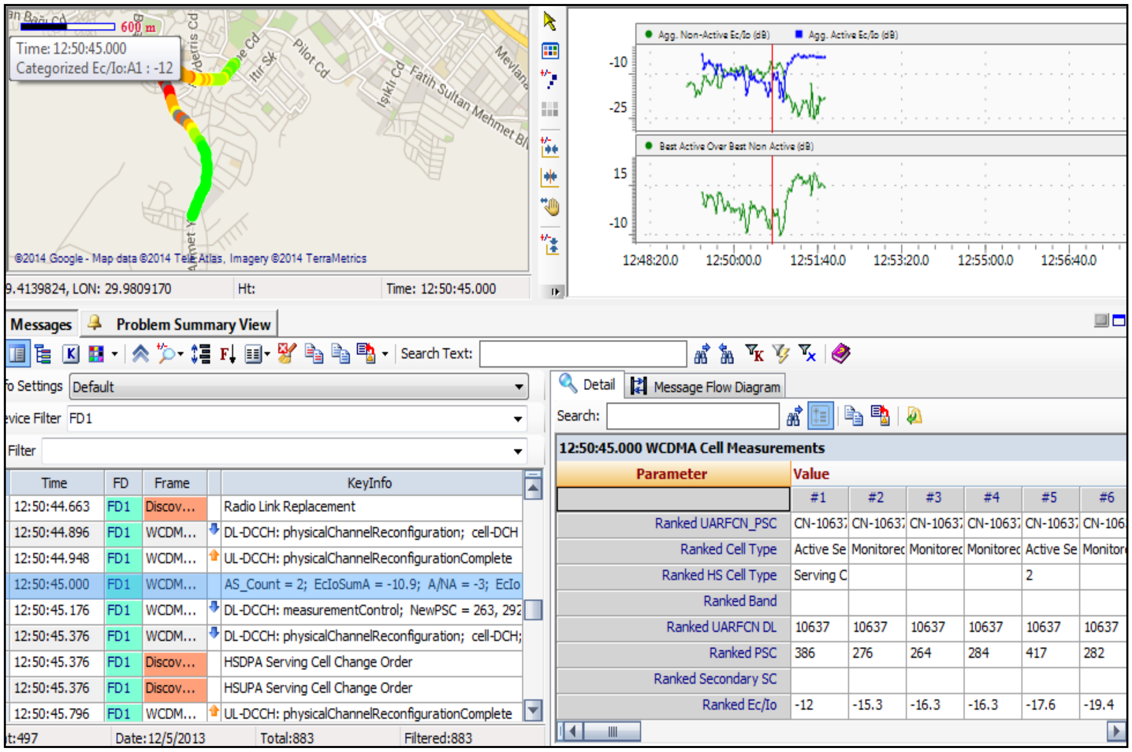


Figure 5.15 Test Measurements for AS2

6. CONCLUSION

In radio network planning the most important two tasks are, assuming capacity and planning the coverage. Operators make these plans on the computers by using some programming tools and after the sites are installed, tests are done to monitor real coverage. Some parameters can be tuned or changed for network quality. The purpose of this master thesis is to find out the effect of active set size on soft handover and improvement of HSUPA throughput. In this thesis, mean active set size, soft handover attempts, quality (Ec/Io), SIR (Signal to Interference ratio) and HSUPA throughput, TTI usage, has been measured as the function of different system parameters and characteristic parameters of radio propagation environment.

To obtain different active set size and HSUPA throughput for each system parameter settings, three drive tests are performed in the same city center. Numerical results for this performance metrics are obtained via TEMS Investigation for the system parameters. System measurement is performed TEMS Investigation version of 15.1 and analyzed by TEMS Discovery version of 10.1. SIR, Ec/Io, TTI usage %, RSCP and HSUPA Throughput are measured.

Effect of AS Size on the SIR, HSUPA throughput and TTI usage % are analyzed. When active set size is increased respectively from 2 to 3 and 3 to 4, UE connects more Node B and this causes much more signaling on the uplink direction. These measurements proves that Node Bs uses much more uplink resources when active set size increases. This causes low 2ms TTI percentage. Percentage of 10 ms TTI increases and uplink throughput decreased with the inversely proportional of AS size in the network.

Lacki [1, p. 72], analyzes the Soft Handover parameters and explains:

“Soft handover gain achieved was varying from 3dB to 5.5 dB, depending on the soft handover window size changed by SHO adding and dropping thresholds and their adding and dropping time to trigger values. These measurements proved that soft handover provides DL transmission power gain which can be seen as improvement of the WCDMA network performance. High bit rate services requires larger SHO areas. Larger overhead is introduced, reducing network performance”

He points out how Overhead is important. Lacki’s thesis shows SIR values and drop call rates improved for higher SHO probabilities but in this thesis it is observed that; SIR values improves when maximum active set size parameter is increased. Main difference between Jaroslav Lacki’s thesis and these measurements are; Lacki’s test was completed indoor sites and this test was conducted outdoor sites. Another difference between two thesis is, HSUPA performance is measured and compared in this thesis.

Another paper about Soft Handover, Abdul-Mawjoud [7, pp.9-10], explains that:

“MS consumes more power on 3-way SHO and so 2-way SHO is recommended. At the same paper, for data 2-way SHO decreases S/N about 14 dB and 3-way SHO by 23 dB.” Abdul-Mawjoud’s [6] paper propose 2 way SHO as it is reccommended for better HSUPA throughputs.

Tests are done in this thesis shows that; SIR values are measured very similar but better SIR range, 15-20, is measured better for AS=2 trial but total samples of SIR > 10, are measured for AS4 trial. According to this thesis, It is recommended recommend that AS size should be used according to operator’s focus points. If HSUPA throughput is low in an area, it is recommended to set AS size to 2. Thus 2 ms TTI will increase. This will effect HUPA throughput and customer satisfaction positively. But as it is seen on the results, before setting AS=2, neighbour optimization should be completed to reduce interference on the network. In addition, another important point is resources for serving NodeBs to use efficent 2ms TTI.

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