Evaluation and Comparison of Soft and Hard Handovers in Universal Mobile Telecommunication (UMTS) Networks

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Abstract

Universal Mobile Telecommunication System (UMTS) is a third generation mobile communication technology based on Wideband Code Division Multiple Access CDMA (WCDMA) and can facilitate the users in much better way as compared to the second generation of mobile communication. UMTS is superior to second generation in terms of bandwidth efficiency, quality of service, speech quality, speed and capacity.

This paper focused on soft and hard handover techniques in UMTS networks and conducted a performance comparison between soft and hard handovers. The project divided into two scenarios: soft handover and hard handover. Soft handover produces better results in terms of uplink transmission power and enables the mobiles to perform the handover at lower power levels. Soft handover benefit from a concept called "soft handover gain" and the network can lower the quality block error ratio (BLER) below the requested level, then the transmission power can be kept at lower levels during soft handover while still providing the same quality to higher layer.

In order to simulate typical UMTS scenarios, OPNET^{v14} modeler is used and a number of users are generating traffic and are free to move in various cells.

الخلاصة

يعد نظام ال UMTS هو الجيل الثالث من تقنية الاتصالات للموبايل و الذي يعتمد على تقنية ال WCDMA و يعطي سهولة للمستخدمين اكثر من تقنيات الجيل الثاني. ان UMTS اكثر منفعة من الجيل الثاني حيث يوفر كفاءة حزمة اكثر , نوعية الخدمة احسن, نوعية الكلام احسن و ايضا سعة السرعة افضل.

هذا المشروع يركز على تقنيات soft و hard handover في شبكات ال UMTS و يعمل مقارنة بينهم. هذا المشروع ينقسم الى قسمين: الاول خاص لل soft handover و الثاني خاص لل hard handover. حيث القسم الاول يولد نتائج احسن في سياق مقدار الطاقة المرسلة و ايضا يمكن الموبايل لانجاز عملية التسليم في مستوى طاقة اقل.

هذا المشروع انجز بواسطة برنامج modeler OPNET^{v14} مع عدد من المستخدمين يولدون حمل على النظام و ايضا يتحركون بحرية حول عدة خلايا.

1. Introduction

Today mobile wireless communications are commonly seen as one of the most advanced form of human communications ever. The last decade Global System for Mobile Communication (GSM) technology has been a leading force in this revolution. Simultaneously with the phenomenal deployment of wireless networks and distribution of user terminals, also the Internet has seen a similar revolutionary growth. The success of both technologies offers a great opportunity to provide integrated services using a wireless network. In order to support multimedia, web, email and other data services in a broadband wireless network, standards have been proposed by the Third Generation Partnership Project (3GPP) leading to the creation of the Universal Mobile Telecommunications System (UMTS). Besides providing changes in the network infrastructure, the UMTS specifications point out the evolution path from GSM circuit switched networks towards packet switched technologies offering higher transmission rates. Based on the service requirements the UMTS Terrestrial Radio Access Network (UTRAN) has been designed. A key requirement in the bearer capabilities is the handover. Principally handover is necessary to support mobility of

users and to enable the interoperability of different network technologies (e.g. between UMTS and 2nd generation systems as GSM) [1].

The telecommunication landscape has been dramatically changed during the last two decades by powerful forces; among them the emergence of wireless mobile communication and the growth of wireless networking. There has been an explosive growth in the use of different communication technologies, as mobile telephony has offered mobile communication between people, and wireless networking has provided flexible communication between computers. This change of the technological landscape also means that the radio systems of today are challenged by the increasing amount of capacity-demanding services. The services span from traditional conversational audio to conversational video, voice messaging, streamed audio and voice, fax, telnet, interactive games, web browsing, file transfer, paging and e-mailing. No single radio system can effectively cover all these services from a multi-service point of view, if QoS requirements are to be met. Consequently, the development moves towards interworking between different but complementary radio systems that together can provide this unparalleled level of services [2].

There are many alternatives to an interworking solution but research has shown that the complementary characteristics of Universal Mobile Telecommunications System (UMTS) and Wireless Local Area Network (WLAN) make them ideal for interworking. UMTS provides a low-bandwidth circuit- and packet-switched service to users with relatively high mobility in large areas whereas WLAN provides a high-bandwidth packet-switched service to users with low mobility in smaller areas. The WLAN therefore complements UMTS on the packet-switched services. The natural trend today is to utilise the high-bandwidth WLANs in hot spots and switch to UMTS networks when the coverage of WLAN is not available or the network condition in the WLAN is not good enough. This, however, also implies that some sort of handover mechanism must be in place to ensure that any ongoing connections are handed over to the new network without breaking or deteriorating the connection. At present, no such mechanism exists by nature. The only way to switch between the two networks is to sign off the first network and then sign on to the next network and start a new connection. The interworking between UMTS and WLAN, where packet-switched services can be used interchangeably across network borders, is therefore far from realized [2].

The objective of this work is to study the network technology UMTS and how interworking best can be achieved between the main important parts. This involves describing the technology to the extent that is necessary for understanding the basic network dynamics and the mobility management capabilities. Moreover, it involves a discussion of UMTS handover techniques.

2. Universal Mobile Telecommunication System (UMTS)

Universal Mobile Telecommunications System (UMTS) is a third generation (3G) wireless protocol that is part of the International Telecommunications Union's IMT-2000 vision of a global family of 3G mobile communications systems. UMTS is expected to deliver low-cost, high-capacity mobile communications, offering data rates up to 2-Mbps. The UMTS model suite allows you to model UMTS networks to evaluate end-to-end service quality, throughput, drop rate, end-to-end delay, and delay jitter through the radio access network and core packet network. It can also be used to evaluate the feasibility of offering a mix of service classes given quality of service requirements. The UMTS model of the packet wireless network is based on 3rd Generation Partnership Project (3GPP) Release 1999 standards. The network architecture of this release is divided into the radio access network (RAN) and the core network as shown in Figure 1. The UMTS module models the UMTS RAN and the UMTS functionality of the core network (highlighted elements in Figure 1). The radio access network for UMTS contains the User Equipment (UE), which includes the Terminal Equipment (TE) and Mobile Terminal (MT), and the UMTS Terrestrial Radio Access Network (UTRAN), which includes the Node-B and Radio Network Controller (RNC) [3].

UMTS uses Wideband Code Division Multiple Access (W-CDMA) access scheme. This version of W-CDMA uses direct spread with a chip rate of 3.84 Mcps and a nominal bandwidth of 5 MHz. The model supports one of W-CDMA's two duplex modes: Frequency Division Duplex (FDD). Time Division Duplex (TDD) is not supported. In FDD mode, uplink and downlink transmissions use different frequency bands. The radio frame has a length of 10 ms and is divided into 15 slots. Spreading factors vary from 256 to 4 for an FDD uplink and from 512 to 4 for an FDD downlink. With these spreading factors, data rates of up to 2 Mbps are attainable.

2.1 Network Architecture

The UMTS network architecture (Release 99) consists of three domains: The User Equipment (UE) domain, the UMTS Terrestrial Radio Access Network (UTRAN) domain and the Core Network (CN) domain. See Figure 1 [4].

The UE domain represents the equipment used by the user to access UMTS services while the UTRAN domain and the CN domain, together known as the infrastructure domain, consist of the physical nodes which perform the various functions required to terminate the radio interface and to support the telecommunication services requirements of the user [4].
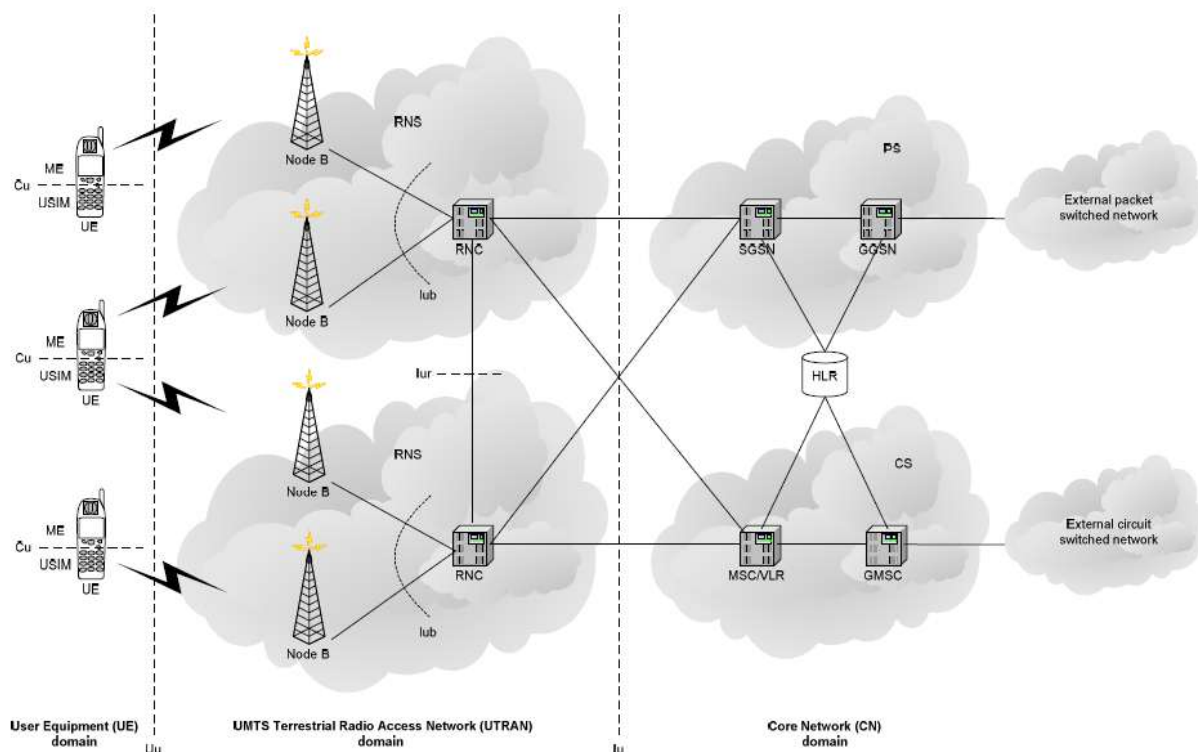

Figure 1 UMTS Network Architecture

1. UE Domain

The UE domain encompasses a variety of equipment types with different levels of functionality such as cellular phones, PDAs, laptops etc. These equipment types are typically referred to as user equipment. The UE domain consists of two parts: the UMTS Subscriber Identity Module (USIM) and the Mobile Equipment (ME).

The USIM is a smartcard that contains user-specific information and the authentication keys that authenticates a user's access to a network. The USIM is physically incorporated into a SIM

card and linked to the ME over an electrical interface at reference point Cu. The ME is a radio terminal used for radio communication with the UTRAN domain over the Uu radio interface. [5].

2. UTRAN Domain

The UTRAN domain handles all radio-related functionality. It consists of one or more Radio Network Sub-systems (RNS), where each RNS consists of one or more Node Bs and one Radio Network Controller (RNC).

The Node B, also known as a Base Station and equivalent to the Base Transceiver Station (BTS) from GSM, converts the signals of the radio interface into a data stream and forwards it to the RNC over the Iub interface. In the opposite direction, it prepares incoming data from the RNC for transport over the radio interface. The area covered by a Node B is called a cell.

The RNC is the central node in the UTRAN and equivalent to the Base Station Controller (BSC) from GSM. It controls one or more Node Bs over the Iub interface and is responsible for the management of all the radio resources in the UTRAN. The RNC interfaces the CN domain over the Iu interface. If there are more than one RNC, they can be interconnected via an Iur interface. [5].

3. CN Domain

The CN domain is responsible for switching and routing calls and data connections between the UTRAN domain and external packet and circuit switched networks. It is divided into a Packet Switched network (PS), a Circuit Switched network (CS) and a Home Location Register (HLR).

The PS network consists of a Serving GPRS Support Node (SGSN) and a Gateway GPRS Support Node (GGSN). The SGSN is responsible for routing packets inside the PS as well as handling authentication and encryption for the users.

The GGSN serves as the gateway towards external packet switched networks like the Internet, Local Area Networks (LANs), Wide Area Networks (WANs), General Packet Radio Service (GPRS) networks, Asynchronous Transfer Mode (ATM) networks, Frame Relay networks, X.25 networks etc., and thus completes the routing function of the SGSN. The CS network consists of a Mobile Services Switching Centre (MSC)/Visitor Location Register (VLR) and a Gateway MSC (GMSC). The MSC/VLR serves as a switch and database. The MSC part is responsible for all signalling required for setting up, terminating and maintaining connections, and mobile radio functions such as call rerouting, as well as the allocation/deallocation of radio channels, i.e. the switching function. The VLR part is controlled by the MSC part and is used to manage users that are roaming in the area of the associated MSC. It stores information transmitted by the responsible HLR for mobile users operating in the area under its control, i.e. the database function.

The GMSC serves similar to the GGSN as the gateway towards external circuit switched networks like other Public Land Mobile Networks (PLMNs), Public Switched Telephone Networks (PSTNs) and Integrated Service Digital Networks (ISDNs) etc. The HLR is a database located in the user's home system that stores all important information relevant to the user, e.g. telephone number, subscription basis, authentication key, forbidden roaming areas, supplementary service information etc. The HLR also stores the UE location for the purpose of routing incoming transactions to the UE. [5].

2.2 Handovers [4]

Handovers are the basic means of providing mobility in cellular architectures. In UMTS systems different handover types have been introduced to cope also with other requirements as load control, coverage provisioning and offering quality of services.

Handover aims to provide continuity of mobile services to a user traveling over cell boundaries in a cellular infrastructure. For a user having an ongoing communication and crossing the cell edge, it is more favorable to use the radio resources in the new cell – also called the target cell – because the signal strength perceived in the "old" cell worsens as the user penetrates the

target cell. The whole process of tearing down the existing connection in the current cell and establishing a new connection in the appropriate cell is called "handover". The ability of a cellular network to perform efficient handovers is crucial to offer attractive services as real-time applications or streaming media as planned in third generation networks.

Especially the number of "handover failures" – the situation in which the handover procedure cannot be completed – has to be further reduced compared to previous generation cellular communication systems as GSM. The cause for a handover failure ranges from signaling failures to the lack of resources in the target cell, making it impossible for a new user to be accommodated. In high performance networks where there is a trend towards the use of smaller cells to increase the capacity, the handover process becomes even more important as more frequent handovers are needed.

An efficient handover algorithm can only be implemented with the help of appropriate resource and user location management. Resource management means that there exists a way to establish, maintain, release and control connections in the radio access layer. In UMTS systems the major part of the control signaling between UE and UTRAN is done by the Radio Resource Control (RRC) protocol. Some of the functions implemented in the RRC protocol that are important in our discussion around handovers are cell selection, UE measurements, SRNS relocation and control of radio bearers, physical and transport channels. Most of the RRC functionality is implemented in the RNC.

User location management means keeping track of the UE's location. Some of this information is stored in functional entities in the core network: the Home Subscriber Server (HSS) and the Mobile Switching Center (MSC); but mainly the RRC protocol operating between the UE and UTRAN – the RNC – fulfils connection mobility functions related to handovers.

WCDMA handovers can be classified in different ways. Some research works distinguish intra-frequency, inter-frequency and WCDMA to GSM intersystem handovers. In this discussion another classification is used. Hard, inter-system and soft & softer handovers are discussed separately as this reflects more the scope of this research while the first classification is merely focused on the measurement method used.

UTRA FDD mode supports soft and softer handovers. Hard and inter-system handovers are supported in both TDD and FDD mode.

2.2.1 Hard handover

Hard handover is the handover type where a connection is broken before a new radio connection is established between the user equipment and the radio access network. This is the handover type used in GSM cellular systems where each cell was assigned a different frequency band. A user entering a new cell resulted in tearing down the existing connection before setting up a new connection at a different frequency in the target cell. The algorithm behind this handover type is fairly simple; the mobile station performs a handover when the signal strength of a neighboring cell exceeds the signal strength of the current cell with a given threshold. In UMTS hard handovers are used to for example change the radio frequency band of the connection between the UE and the UTRAN. During the frequency allocation process for UMTS, it has been planned that each UMTS operator will have the possibility to claim additional spectrum to enhance the capacity when a certain usage level will be reached. In this case several bands of approximately 5MHz will be in use

by one operator, resulting in the need for handovers between them. Hard handovers are also applied to change the cell on the same frequency when no network support of macro diversity exists [3]. Otherwise stated, when a UE with a dedicated channel allocated, roams into a new cell of a UMTS network, hard handover is chosen when soft or softer handover is impossible. A third case of hard handovers are the so-called inter-mode handovers. This allows for changes between the FDD and the TDD UTRA modes. This handover type is sometimes also classified as inter-system

handover as the measuring methods used are very similar to WCDMA-GSM handovers. Although from technical point of view these inter-system handovers can be seen as a type of hard handovers.

The main problem surrounding hard handovers in GSM systems are the – sometimes high – blocking probabilities experienced by users entering a new cell. This probability can be reduced by giving priority to handover users over new users, which can be done by for example reserving a certain part of the capacity in each cell for users with ongoing communication. On the other hand this results in a less efficient use of the capacity of the cellular systems or higher blocking probabilities for new users. These considerations and other CDMA-specific arguments have lead to the choice of additional handover types to coexist in the WCDMA access network: soft and softer handover algorithms counter some of the disadvantages of CDMA systems and hence increase overall system performance. Typically hard handovers are only used for coverage and load reasons, while soft and softer handover are the main means of supporting mobility.

2.2.2 Inter-system handover

Inter-system handovers are necessary to support compatibility with other system architectures. Mainly handovers between UTRAN and the GSM radio access network will be vital during the rollout of UMTS networks. In the initial deployment phase of 3G networks it is very likely that rural areas will not yet be covered by the WCDMA network. Thus GSM networks will still be used to provide coverage in those areas. On the other hand it looks probable that the additional capacity provided by WCDMA networks will be used to unload the urban GSM network. In the later releases of the 3GPP specifications handovers to other systems than GSM are included.

The signaling procedure for handing over a UMTS user to the GSM system is shown in figure 2 [4]. This example is illustrative for the general procedure followed during handovers. This procedure generally consists of carrying out of measurements, reserving resources and performing the actual handover.

1. Measurement control
2. Measurement report
3. Resource reservation
4. Resource reservation ACK + handover command
5. Handover from UTRAN to GSM
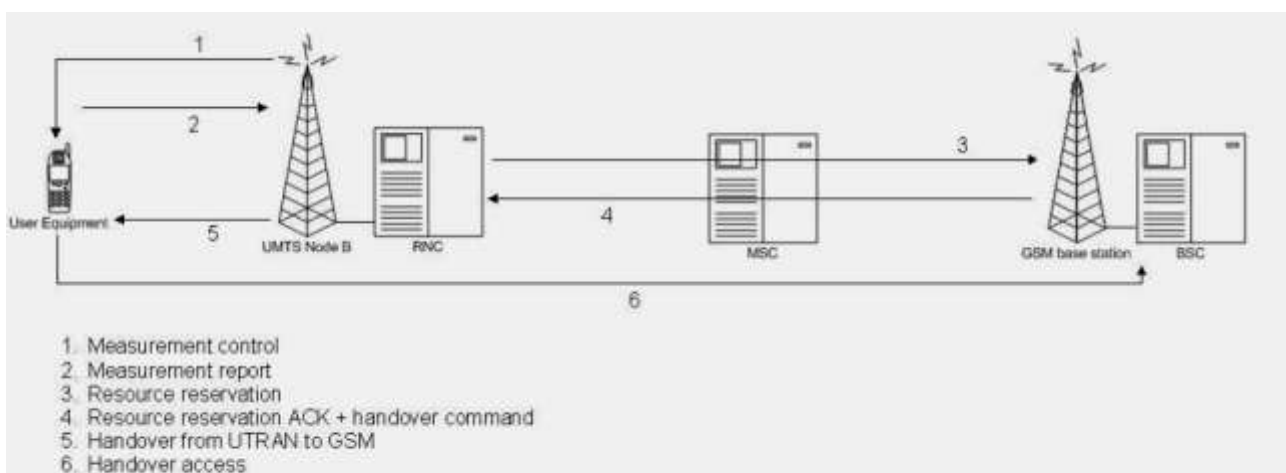6. Handover access

Figure 2 Inter-system handover procedure from UTRAN to GSM

When switching the connection to another system architecture there is need for a measurement on the frequency used by the other system. When there is no full dual receiver available the transmission and reception are halted for a short time to perform measurements on the other frequencies. This is called the compressed mode. As FDD and TDD modes make use of different frequencies, inter-mode handovers also make use of compressed mode to perform measurements on other frequencies needed during the handover.

2.2.3 Soft and softer handover

Soft and softer handover are the CDMA specific handover types implemented in the UMTS system and form one of the most characteristic features of the revolutionary WCDMA access method. In this paragraph the impact of implementing this handover types on the system design is discussed in detail and also the algorithms behind these methods as described in 3GPP specification TR 25.922 are analyzed. A soft or softer handover occurs when the mobile station is in the overlapping coverage area of two adjacent cells. The user has two simultaneous connections to the UTRAN part of the network using different air interface channels concurrently. In the case of soft handover the mobile station is in the overlapping cell coverage area of two sectors belonging to different base stations; softer handover is the situation where one base station receives two user signals from two adjacent sectors it serves. Although there is a high degree of similarity between the two handover types there are some significant differences.

In the case of softer handover the base station receives two separated signals through multi-path propagation. Due to reflections on buildings or natural barriers the signal sent from the mobile stations reaches the base station from two different sectors. The signals received during softer handover are treated similarly as multi-path signals. In the uplink direction the signals received at the base station are routed to the same rake receiver and then combined following the maximum ratio combining technique. In the downlink direction the situation is slightly different as the base station uses different scrambling codes to separate the different sectors it serves. So it is necessary for the different fingers of the rake receiver in the mobile terminal to apply the appropriate de-spreading code on the signals received from the different sectors before combining them together. According to soft handover occurs in 5-10% of the connections. Due to the nature of the softer handover there is only one power control loop active [4].

For soft handover the situation is very similar in the downlink direction. In the mobile station the signals received from the two different base stations are combined using MRC Rake processing. In the uplink direction on the other hand there are significant differences. The received signals can no longer be combined in the base station but are routed to the RNC. The combining follows a different principle; in the RNC the two signals are compared on a frame-by-frame basis and the best candidate is selected after each interleaving period; i.e. every 10, 20, 40 or 80ms. 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.

Figure 3 shows different types of handover [4].

Figure 3 Different Types of Handover
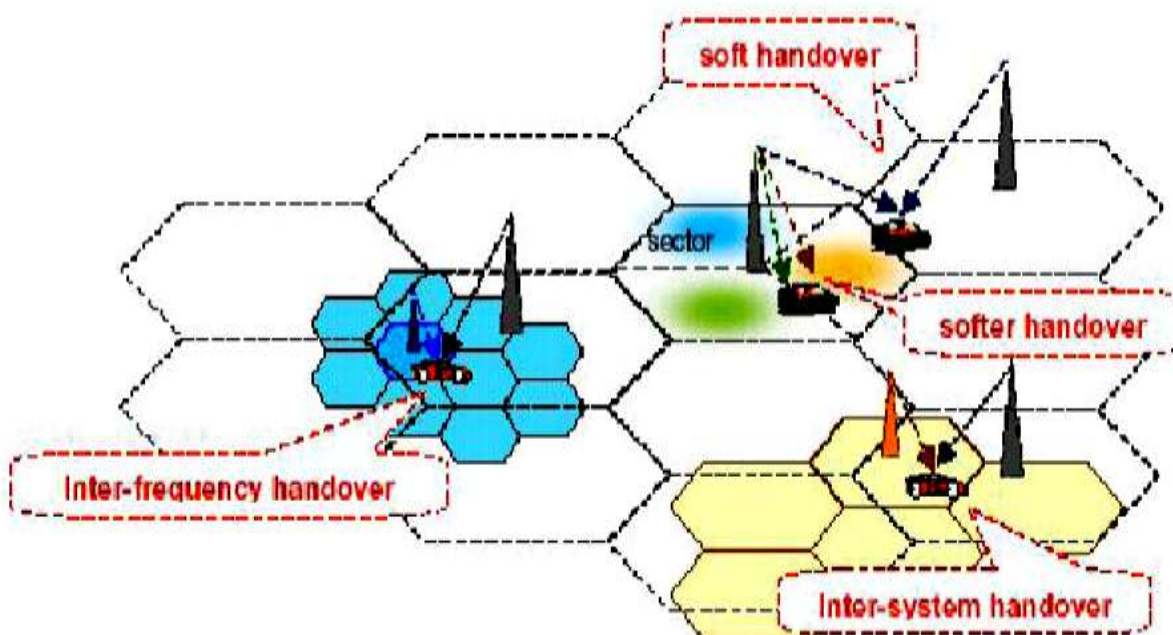
2.2.4 Soft and Hard Handover Process [6]

"Figure 4" represents that a mobile terminal is activated while car is moving from cell 1 to cell 2 and BS1 is the actual serving base station. First curve show E_c/I_o (pilot signal) of BS1 and second curve show E_c/I_o (pilot signal) of second BS2. In (a) the mobile continuously monitors the strength of the signal coming from the serving base station BS1, as the user moves across the boundary of first cell and moves into the second cell. At this time the mobile receives the pilot signal from second base station .The E_c/I_o of BS2 is subtracted from E_c/I_o of BS 1 and if the value is grater than hystheresis margin than hard handover is performed [4]. The value of hystheresis is very crucial because it was introduced in hard handover algorithm to overcome the problem of more frequent handover called the "ping pong" problem. If we have a larger value of hystheresis it causes more delay.

In (b) it is shown that as the car moves across the boundary of two cells at that moment the mobile receives the pilot signal of both base station i.e. BS1 and BS2.If the pilot signal strength of BS2 is greater than BS1 pilot signal strength and the handover condition is fulfilled than soft handover is performed. The mobile continuously communicates with the BS1 and BS2 before dropping the BS1.In (a) a mobile communicates with only one base station at a time.

There are two types of delay introduced during handover one is called the decision delay and the other is called the execution delay. First type of delay deals with the time required in making a decision to perform handoff and the execution delay is the time needed to switch to another base station. In a soft handover the decision delay is less but the execution delay is more than hard handover.
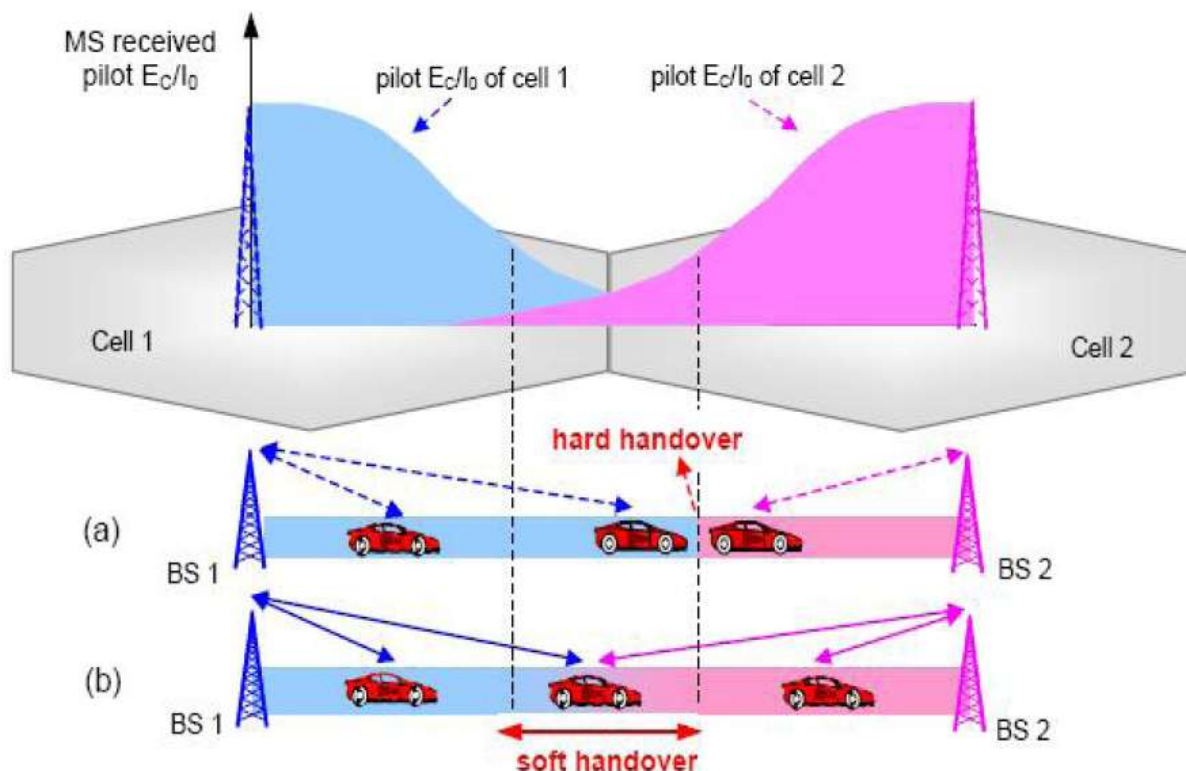

Figure 4 Comparison of Hard and Soft handover

2.2.5 Soft and Hard Handover Controlling Factors [7]

Soft handover has some benefits over traditional hard handover, but it is more complex to implement. There are some parameters on which the soft handover is dependent. These parameters are:

- The minimum amount of threshold required for base station to remain in an active set is called add threshold.
- The amount of threshold required to drop the base station from an active set is called drop threshold
- In order for an active set member to be dropped from the active set, the signal level of that member must be below the drop threshold for a period of time at least equal to Tdrop.
- The soft handover window (SHW) is the difference between add and drop threshold. It shows how long a handover will take on average. The larger the window the more time is required to performed soft handover.
- The formula for effective hand off as a=area of the handoff region/area of the cell.

The benefits of the soft hand off over hard handover is as:

* Power control is introduced.
* Better quality of service achieved in soft handover.
* Lesser delay is required because no hystheresis is involved.
* Less overhead with respect to signaling on network.
* It eliminates the ping pong effect.

3. Simulation Scenarios

The objective of these scenarios are to demonstrate softer and hard handover procedures applied to a mobile UE while it is surrounding a Node B with three sectors (i.e. cells). Also we compare the UE's transmission power between these scenarios.

The Node B has three directional antennas covering an angle of 160 degrees and sectors/cells are positioned every 120 degrees starting from 0 degrees (0, 120, 240). So an overlap of 40 degrees is produced between adjacent cells.

In these scenarios, the UEs follows its trajectory around the Node B causing repeating handovers from one sector to another sector. The UE uploads FTP files to a server at a remote network using UMTS QoS 3 service level.

The RNC UMTS handover parameter soft handover is set to supported in the softer_handover scenario and to not supported in the hard_handover scenario. Parameter active set size is set to 2. The numbers displayed at each sector corresponds to cell_IDs associated with it (e.g. cell_ID 2 is the cell/sector 2).

3.1 Simulation description for scenario: Softer_Handover

The model for this scenario is shown in figure 5. This description is based on some statistics that are defined under "UMTS Handover" group to demonstrate the softer handover procedures. These statistics show the number of cells (i.e. sectors) in UE's active set and which cells are added into and removed from that set during the simulation. You also see the pilot channel E_c/N_o measured by the UE for all the sectors that belong to its monitored set. As the UE moves around the Node B, it measures the pilot channel signal strength coming from all three sectors. Based on these measurements it changes its active set. The following is a description of the softer handover events occurred during the simulation.

a) When the simulation starts, UE gets the strongest signal from sector 1 so it becomes the only member of the initial active set.

b) UE starts moving at 110sec. After some time when it reaches the edge of sector 0 (170sec.) this gets added into the active set, the UE is now in softer-handover between sectors 0 and 1 while it remains in this position (aprox. 1 minute). Notice how during softer-handover the sectors 1 and 2 reports at the same time uplink throughput coming from the UE (see sector uplink throughput

graph), when that happens all duplicated packets are eliminated at the Node B and are not delivered to the RNC.

c) Now the UE moves toward the center of sector 0 (230sec.). UE abandons sector 1 removing it from its active set (250sec.). Then the UE remains in sector 0 for 1 minute.

d) At 350sec.the UE travels to sector 2, now, when it goes into sector 2 and while it remains in the overlapped area between sectors 1 and 2, the UE enters in softer-handover state again (364sec.).

e) The UE continue moving along its trajectory, this time going to the center of sector 2, losing sector 0 and ending its softer-handover state (407sec.).

f) Finally the UE returns to sector 1. Reaching again a softer handover state, but now between sectors 1 and 2, when it lies on the area shared by both sectors (600sec.). Then the UE goes to the center of sector 1, dropping sector 2 from its active set (645sec.).

The results of this scenario are shown in figures 7, 8 and 9.
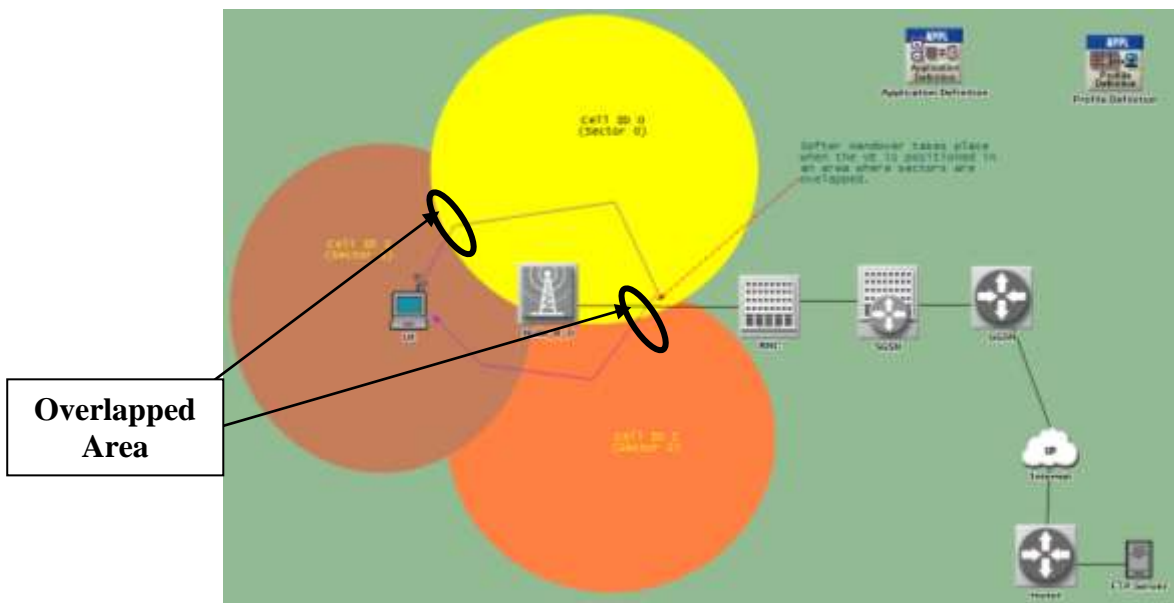
Figure 5 Soft Handover Scenario

3.2 Simulation description for scenario: Hard_Handover

The model for this scenario is shown in figure 6. This description is based on some statistics that are defined under "UMTS Handover" group to demonstrate the softer handover procedures. These statistics show the number of cells (i.e. sectors) in UE's Active Set and which cells are added into and removed from that set during the simulation.

You also see the pilot channel E_c/N_o measured by the UE for all the sectors that belong to its monitored set. As the UE moves around the Node B, it measures the pilot channel signal strength coming from all three sectors. Based on this measurements it changes its active set. The following is a description of the softer handover events occurred during the simulation.

a) When the simulation starts, UE gets the strongest signal from sector 1 so it becomes the only member of the initial active set.

b) UE starts moving at 110sec. After some time when it reaches the edge of sector 0 (170sec.) a hard handover is performed: sector 0 gets added into the active set while sector 1 is removed from it.

c) At 350sec.the UE travels to sector 2, now, a hard handover happens from sector 0 to sector 2 (364sec.).

d) Finally the UE returns to sector 1. Reaching performing another hard handover state, but now from sector 2 to 1 (600sec.). Then the UE goes to the center of sector 1 and remains there (645sec.). The results of this scenario are shown in figures 10, 11 and 12.
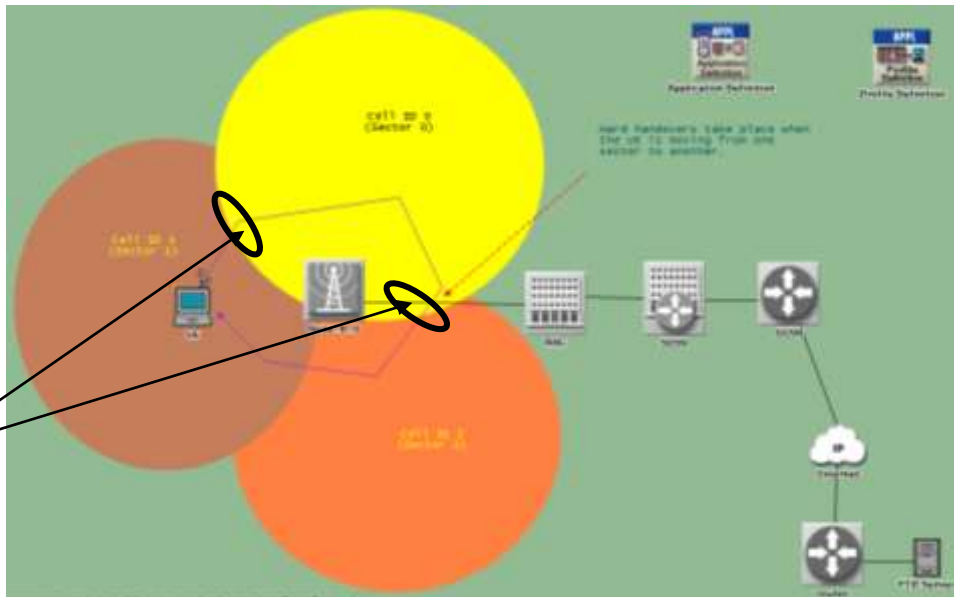

Figure 6 Hrad Handover Scenario

4. Conclusion

In both scenarios, the results for several statistic groups are collected:

UMTS handover, Node Bs Throughput and UE RLC/MAC uplink transmission power. Some of them will show the above-described events that occur during the simulation: UE Pilot Channel E_c/N_o per Sector, UE Handover Active Cell Count, Cells Added to Active Set and Cells Removed from Active Set.

We compared the UE transmission power between both scenarios. The UE in the softer handover scenario uses much less transmission power reducing the cell interference. On the other hand during softer-handovers the UE is taking more network resources.

As you can see during the softer handovers the Node B is receiving traffic through two cells (sectors) simultaneously, while in the hard handover case, just one sector receives traffic at the same time. The average uplink transmission power comparison between these two scenarios is shown in figure 13.

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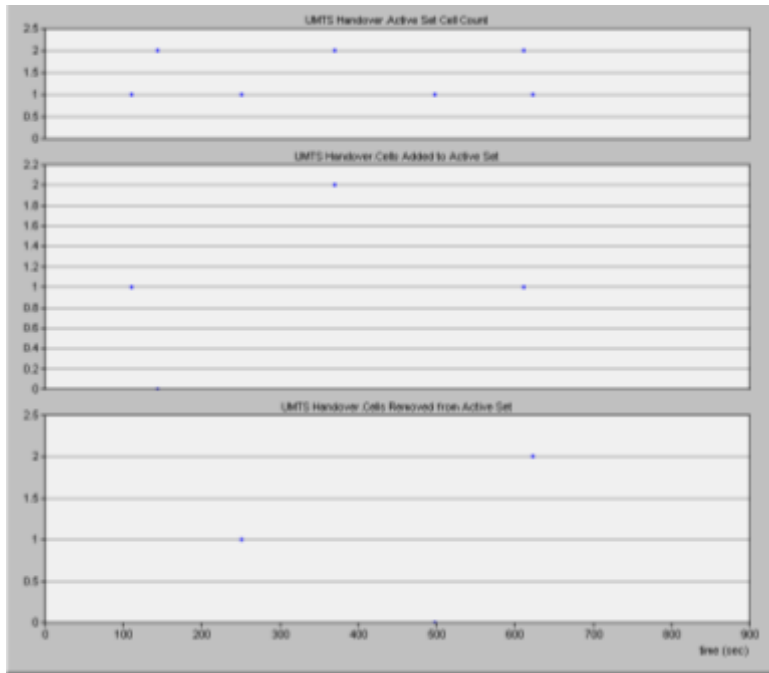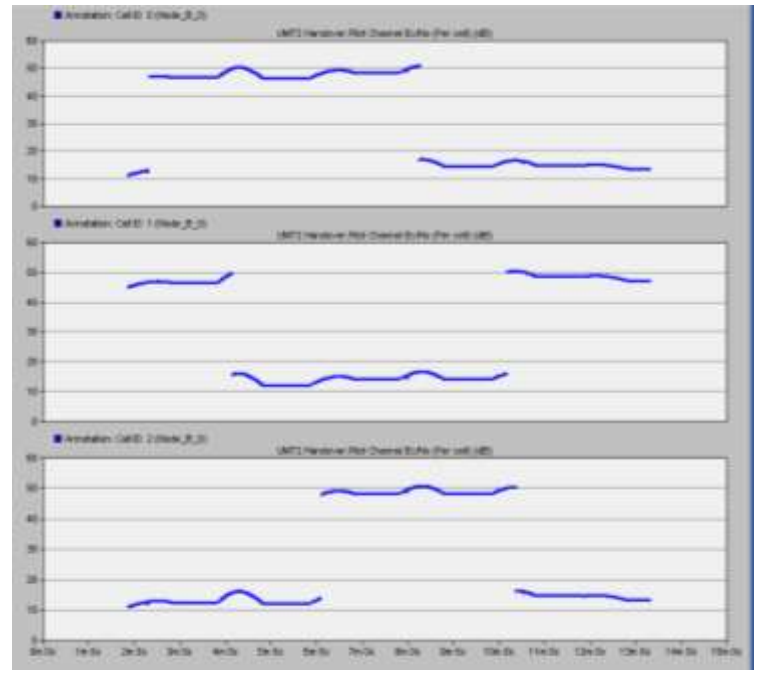
Figure 7 UE Handover Operations

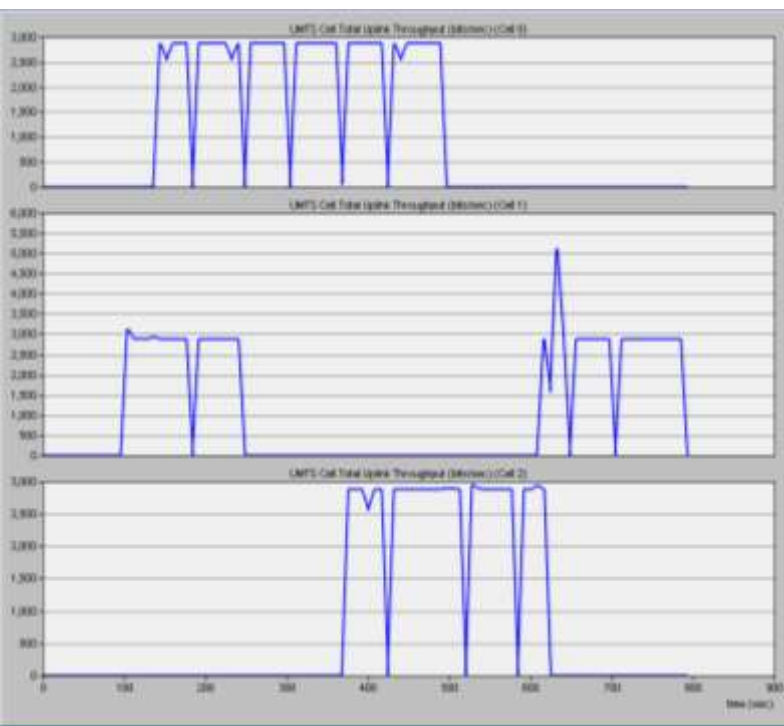Figure 8 Measured Pilot Channel E_c/N_o of the Sectors
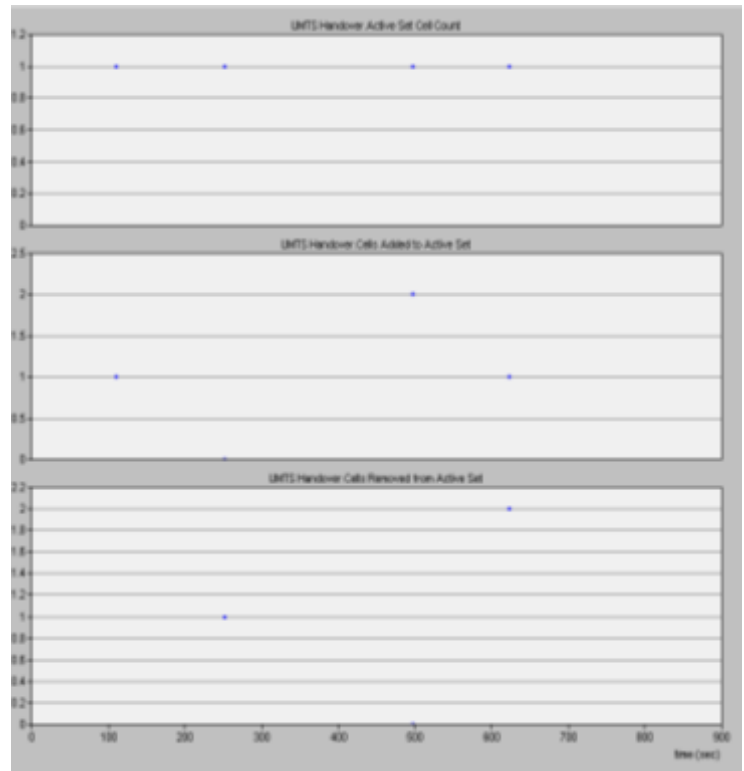

Figure 9 Node_B_0 Cells Uplink Throughput

Figure 10 UE Handover Operations

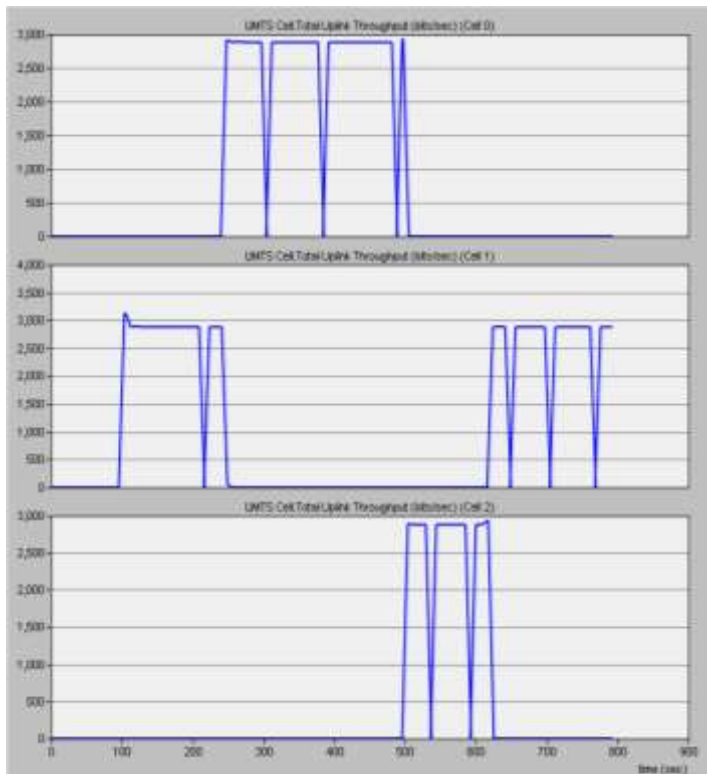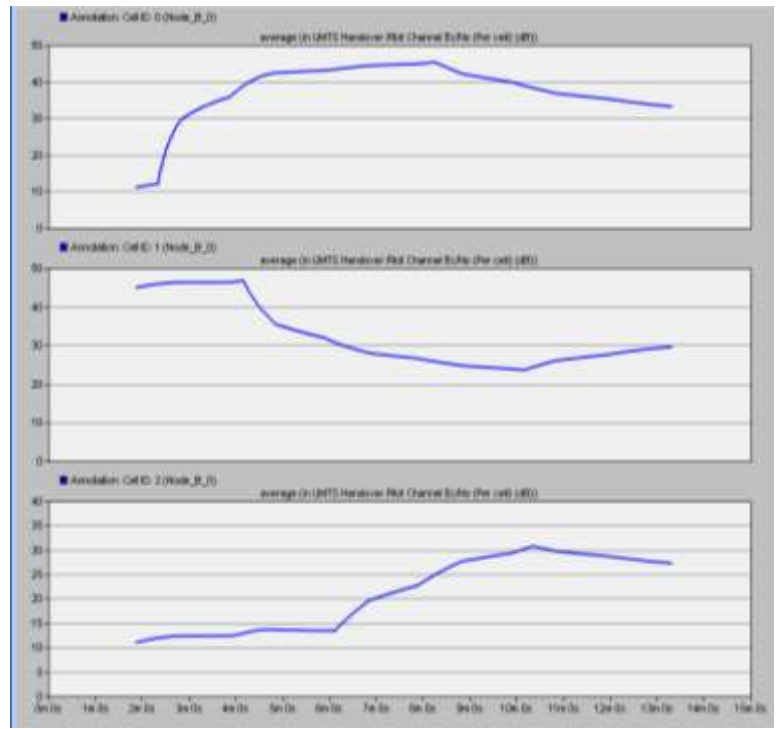Figure 11 Node_B_0 Cells Uplink Throughput
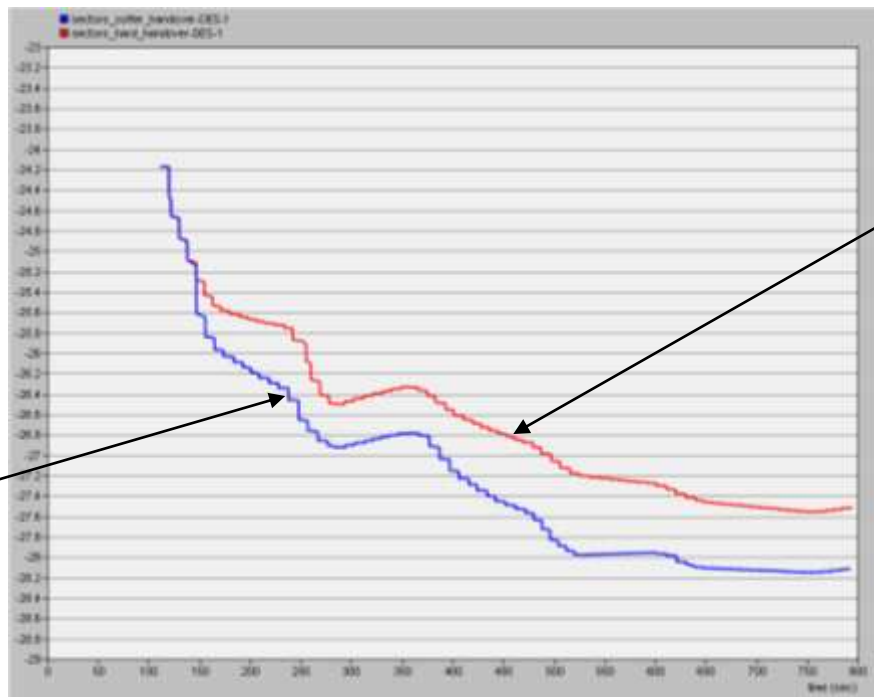
Figure 12 Average Measured Pilot Channel E_c/N_o of the Sectors

Figure 13 Comparisons between the Soft and the Hard Handover