QoS parameters analysis of UMTS handoffs using OPNET™ 14.5

[1]Renuka,[2]Vinit Grewal
[1]Student, [2]Assistant Professor
[1]Department of Electronics and Communication Engineering,
[1]Guru Nanak Dev University Regional Campus Jalandhar, Jalandhar ,India

---

***Abstract* – This research paper is based on simulation and analysis of UMTS handoffs. Evaluation of hard handoff and soft handoff based upon various QoS parameters as uplink transmission power, active set count, pilot channel, number of cells removed from active set, etc. Based upon simulations using OPNET™ 14.5 it is revealed that soft handoff support continuity of signal during mobility over geographical region.**

***Index Terms* – UMTS, QoS, GSM, UTRAN, OPNET™ 14.5.**

I. INTRODUCTION

Mobility is the main advantage of mobile cellular systems. Communicate anywhere, at any time was the great success of wireless communications. Now a day's, continuous service is achieved by supporting handoff from one cell to another. It is regularly initiate either by crossing a cell boundary or by decrease in quality of the signal in the current channel. Universal Mobile Telecommunication Service (UMTS) is cellular technology also known as 3G mobile communications offers 3G services over mobile in wireless communication. In mobile communication Global System for Mobile (GSM) and internet augmentation direct to provide integrated services over mobile using wireless network. The background of telecommunication has been radically changed through the last two decades because of different demands like appearance of wireless mobile communication and the expansion of wireless networking. Emergence of different mobile communication technologies, as mobile telephony has presented mobile communication between users, and wireless networking has provided flexible communication between end terminals (computer). To this change of the technological background also challenged the today radio systems by the increasing amount of capacity-demanding services (Castro 2001). To support multimedia services as conversational video, voice messaging, streamed audio and voice, fax, telnet, interactive games, web browsing, file transfer, paging and e-mailing etc and offer high data rates for these multimedia services over mobile, standard have been projected by 3GPP leading to creation of UMTS (Holma 2000). UMTS is superior to second generation in terms of bandwidth efficiency, quality of service, speech quality, speed and capacity. In addition providing changes in the network infrastructure, the UMTS specifications identify the evolution path from GSM circuit switched networks towards packet switched technologies offering higher transmission rates. Based on the service demand the UMTS Terrestrial Radio Access Network (UTRAN) has been planned. During mobility mobile terminals allow users to access services. This characteristic has provoked the hasty development in industry of mobile network. A key condition in the bearer capabilities in UMTS is the handoff to support mobility over geographical region. Handoff is the important function to deal with the mobility of the mobile users (Marichamy1999). There are two types of handoffs hard handoff and soft handoff. As compared to GSM used conventional hard handoff in mobile networks, the soft handoff being proposed for 3G has better performance on both link and system level which is special feature of UMTS mobile network. 3G systems are designed for multimedia communications with higher data rates and flexible communication capabilities (Mihailescu 1999). UMTS offers simultaneous multiple services for one user and services with guaranteed Quality of Service (QoS) (Saad 2008).

II. BACKGROUND

UMTS is also called as 3G. UMTS upgraded from GSM via General Packet Radio Service (GPRS) and Enhanced Data Rates for Global Evolution (EDGE). Because GSM is restricted to maximum data rates of less than 50 kbps and not support video telephony. To enhance data rates enhanced data rates for global evaluation (EDGE) technology added to GSM to support up to 472 kbps data rates, still failed for voice applications (Schiller 1999). To offer high data rates to support different multimedia services over mobile, standard have been projected by 3GPP leading to creation of UMTS. Main aim of UMTS is to provide global roaming and it also supports various multimedia services as email, web browsing, and voice with higher data rates of 384 kbps even as moving and 2 Mbps. UMTS work with internet protocol and also it is superior to 1G and 2G systems in efficiency. UMTS support various applications by providing higher bandwidth to users and ecommerce (Dahlman 1998). It provides video conferencing and streaming, voice over internet protocol, music, sports gaming, chat etc for the users and for ecommerce it provides speedy teleporting / VPN access, sales force computerization, video conferencing and concurrent financial information. The concept of UMTS and its architecture, 3G mobile communication systems delivers low cost services with supporting high data rates explained by 3GPP Version (9.2.0) (2011). UMTS architecture consists three parts user equipment (UE), UMTS terrestrial radio access network (UTRAN), and core network, which calculates approximate end-to-end service quality and allow network to guarantee required QoS to services. QoS support in UMTS is based on the hierarchical structure, defined in 3GPP specification TS 23.107. End to end QoS is supported by three bearer services including UMTS bearer service, local bearer service, external bearer service. UMTS supports traffic with very different bandwidth and QoS requirements. To provide required QoS to multimedia services, UMTS further supports five service classes traffic class, conversational class, streaming class, interactive and background class (Sharma 2004). These classes are distributed based on QoS parameters of services that are throughput, maximum packet size, transfer delay and traffic handling priority etc.

III. Literature Survey

An extensive work has been done in literature for providing appropriate handoff scheme in UMTS while catering QoS needs of the network at the same time. In 1987 Europe produced GSM 2G standard issued by ETSI and in 1993 first GSM mobile phone became available and fax, data and sms services were launched. Schiller (2008) explained the requirements of hand off process that are resource management and different traffic conditions during movement of the UE/cell phone from one cell to another during an ongoing session as interference experienced by the user's equipment from the near cell. Jayasuriya (2001) had described different types of handoffs and handoff algorithms. Hard handoff is also known as break before make because this type of handoff firstly breaks connection and after breaking makes a new connection with BS. GSM uses hard handoffs which break connections during handoff and not able to support high demanding multimedia services as Voice Over Internet Protocol (VOIP), heavy web browsing etc. These two issues led to number of researchers to explore their work area. J. N. et al (1994) explained evaluation of GSM that offers up to 472 kbps data rates, but unable to support for voice applications and lead to creation of UMTS. Main aim of UMTS is to provide mobility without connection break and it also supports various multimedia services. Soft handoff is special feature of UMTS which is also known as make before break because this type of handoff firstly build connection and after building a new connection with base station (BS), break connection with old BS, supported by Wide Code Division Multiple Access (WCDMA) access method (Homla 2001). Kim and Sung (1999) explained another type of handoff called softer handoff, implemented in the UMTS system. Further research also been done by researchers on UMTS architecture to support soft and softer handoffs, network architecture consists of UE, BS's, Radio Network Controller (RNC), Gateway GPRS Support Node (GGSN), Serving GPRS Support Node (SGSN) and Server. Wong (1997) explained problem of the situation where one base station receives two signals from one user from two adjacent sectors which BS serves during softer handoff in UMTS. To resolve this problem rake receivers were used in transrecievers of BS. Stojmenovic (2002) had given detail description of UMTS handoffs requirements, QoS requirements of different bearer services and their management in UMTS (Garg 2000). To provide required QoS to multimedia services, UMTS support five service classes traffic class, conversational class, streaming class, interactive and background class, which are divided based on QoS metrics which evaluate performance of the system during different handoffs (Sharma 2004).

IV. UMTS Architecture

UMTS is part of the International Telecommunications Union's IMT-2000 vision of a global family of 3G mobile communication system. UMTS delivers low cost, high-capacity mobile communications, supporting data rates up to 2-Mbps. The

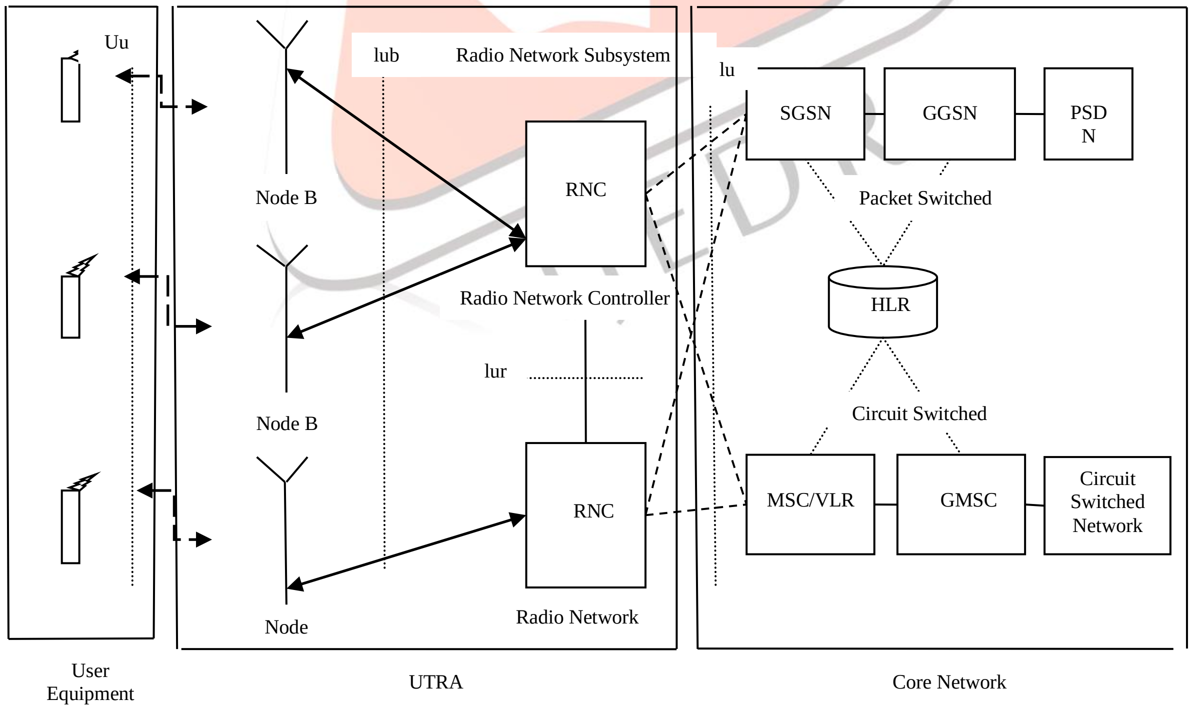

Figure 4.1 UMTS Architecture

UMTS architecture shown in figure 4.1 allows networks to estimate QoS through the radio access network and core packet network. It can also evaluate the possibility of offering different QoS requirements to different service classes. The UMTS network architecture is particularly according to supply higher flexibility to users than second generation networks could support (Laukkanen 2000). UMTS architecture as shown in figure 2.1 consists of three parts called fixed infrastructure or core network of UMTS, UE, and UTRAN which is main part of UMTS architecture, it involves RNC and Node-B (BS). Node-B performs radio resource management and RNC control air interface resource of UE and Node-B and handoff process. Core network consists of packet switched and circuit switched connected to UTRAN, where circuit switched elements of core network are visitor location register (VLR), mobile services switching center (MSC), and packet switched domain elements are serving GPRS support node (SGSN), gateway GPRS support node (GGSN). Core network interfaces to all other external cellular telecommunication networks counting public phone network, and provide central processing for system as specified by 3GPP version 3.0.1 (1999).

V. HANDOFF

Handoffs are used to gives ability of mobile services to a user roaming over cell boundaries in a cellular infrastructure. During constant communication of user and passage of the cell boundary, so it is positive to use the radio resources in the next cell as the signal level received in the old cell worsens as the user enters the target cell. The course of action of breaking the presented connection with the present cell and making a new connection with the suitable cell is called handoff (Marichamy 1999). In UMTS (3GPP) the handoff process consist two main functions that's are acquiring the resources, processing measurements and executing the handoff algorithm. In UMTS system different handoff types have been introduced to deal with necessities as throughput, delay for offering quality of services in UMTS cellular system. The ability of a cellular network to execute efficient handoffs is key to offer real-time applications or streaming media as intended in third generation networks. This chapter gives a brief introduction of UMTS architecture, handoff procedure and types of UMTS handoffs, QoS traffic classes and parameters. In UMTS there are different types of handoffs. Handoffs handle the efficiency of UMTS performance. There are two major types of handoffs in UMTS, the hard handoff and the soft handoff. Soft and softer handoffs supports UTRAN FDD mode only. Hard and inter-system handoffs are supported in both TDD and FDD mode. These are explained below.

HARD HANDOFF

This handoff called break before make. During user movement from one cell to other cell, firstly connection to the existing cell is break and then new connection formed to new cell. Connection is broken before a new radio connection is established between the user equipment and the radio access network. This type of handoff used in GSM cellular systems where each cell was assigned a different frequency band (Zhang 2002). UE 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. In UMTS for the duration of change of radio frequency band between the UE and the UTRAN hard handoff used. In process of frequency allocation in UMTS, it has been premeditated that to enhance the capacity of system each UMTS operator can argue supplementary spectrum at a definite level. For this case 5MHz bands will be used by one operator (Viterbi 1994), which results handoffs between them. Second case of hard handoff in UMTS cellular system is during mode change of UMTS from FDD to TDD UTRA modes. This is hard handoff type in UMTS handoffs also called inter system handoff example handoff between GSM-UMTS system. Hard handoffs are also functional when UE roams to new cell with ongoing call having committed channels allocated and soft handoff is impossible (Homla 2001). Hard handoffs are used for coverage and load reasons.

SOFT HANDOFF

Soft handoff called make before break. When user moves to other region UE first make connection to new cell and then break old connections to old cell. Here UE connected to both cells (old and new) for a while in whole process. UMTS network uses mostly soft handoff for mobility management in network (Kari 1999). Soft handoff is one of CDMA specific handoffs that are quality feature of WCDMA access method implemented in the UMTS system. In soft handoff is case where UE is in overlapping cell coverage area of two sectors having different base stations. The user (UE) has two concurrent connections to the UTRAN part of the UMTS network using separate air interface channels simultaneously. During soft handoff in the downlink direction the mobile station or UE received signals from the two different base stations as shown in figure 2.2 that are combined using MRC Rake processing. In case of uplink direction received signals cannot be combined in the base station hence are routed to the RNC where combining is done using different principles (Chen 2000). Two signals pilot channel and frames are first compared in RNC and after that best signal is selected. To determine the signal to noise ratio of uplink received signals RNC used the outer loop power control algorithm and use the information to chose the best quality frame during the soft handoff.

VI. HANDOFF INITIATIONS

Handoff can be initiated in three different ways which are mobile initiated, network initiated and mobile assisted (Zhang 2002).
Mobile Initiated- Handoff initiated by user equipment or mobile called mobile initiated handoff. The UE makes quality measurements regularly, select the best BS, and switches, with the network's support. This type of handoff is normally initiated because of the poor link quality measured by the mobile.
Network Initiated- Handoff initiated by the RNC. The BS makes the measurements and sends information to the RNC, which makes the decision whether to start handoff or not. Network initiated handoff is executed to control traffic distribution between cells.
Mobile Assisted- This handoff is special type of handoff where measurements makes by UE and RNC both but RNC which is responsible for handoff decision. The mobile reports the measurement results from nearby BSs and the network which further makes the decision of handing over or not.

VII. HANDOFF PROCEDURE AND MEASUREMENTS

The mobility of the end users causes dynamic variations both in the link quality and the interference level, sometimes requiring that a particular user change its serving base station. This process is known as handoff. The handoff procedure can be divided into three phases: measurement, decision and execution phases as shown in figure 7.1. During measurement phase, to make the handoff decision all the compulsory information desirable to make the handoff is measured. Basically downlink measurements performed by the mobile are the $\frac{Ec}{Io^2}$ of the Common Pilot Channel (CPICH) of its serving base station and neighboring base stations.

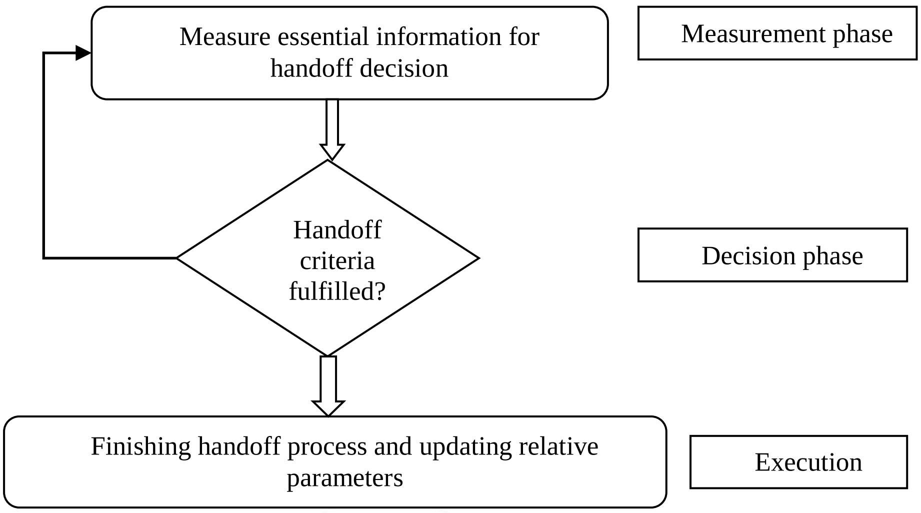

Figure 7.1 Handoff Procedure

For some types of handoffs, other measurements are required to do like the relation timing information between the base stations to adjust the transmission timing in soft handoffs to allow coherent combining in the rake receiver. Otherwise, the transmissions from the different base stations probably difficult to combine and particularly the power control operation in soft handoff will undergo additional delay. During the handoff in the decision phase, the results that are measured are compared against the predefined thresholds and then it is decided whether to initiate the handoff or not (Kim 1999). In the execution phase, the handoff process is completed and the relational parameters are changed according to the different types of handoffs. For example, in the execution phase of the soft handoff, the user equipment enters or leaves the soft handoff state, a new base station is added or released, the active set is updated and the power of each channel concerned in soft handoff is adjusted.

VIII. Related works

To study the network technology of UMTS and UMTS handoffs, hard handoff and soft handoff process are evaluated with simulation. Figure 8.1 scenario created to study and analysis the various handoff parameters. There are three user equipments user A, user B, and user C_1 connected with six BS's these are nb_0, nb_1, nb_2, nb_3, nb_4, nb_5. BS's are connected to CN through RNC.

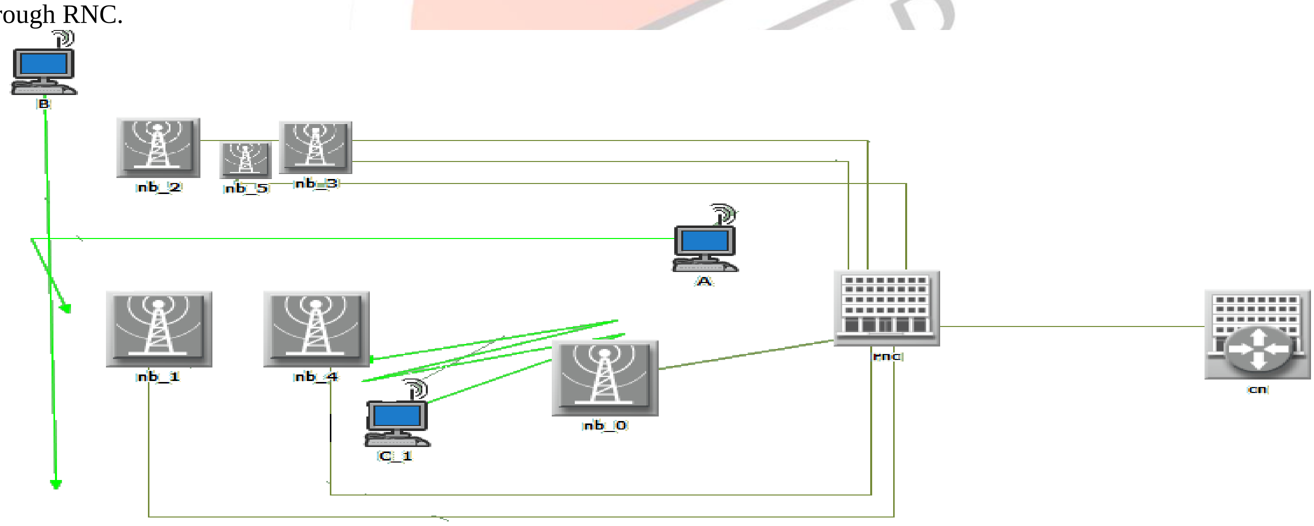

Figure 8.1 UMTS Handoff Network Scenario

IX. Simulated Results

Figure 9.1 and figure 9.2 shows the statistic which reports the number of the cells in the active set of the surrounding UE, which varies during handoff. Active cell count of three UEs of UMTS network evaluated during hard handoff is shown in figure 9.1 and for soft handoff as shown in figure 9.2. Simulation result reveals that during every hard handoff each UE connected to only one BS or node_b, UE first break connection to old node_b and during soft handoff each UE can be connected to more than one node_b and break connection to old node_b after successful handoff. Results show that soft handoff support mobility without connection break.

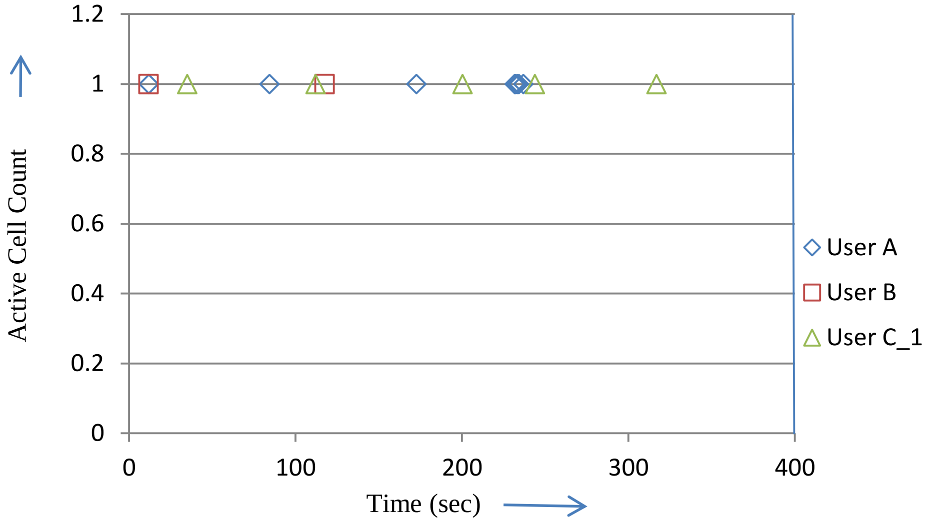

Figure 9.1 UEs Active Cell Count for Hard Handoff

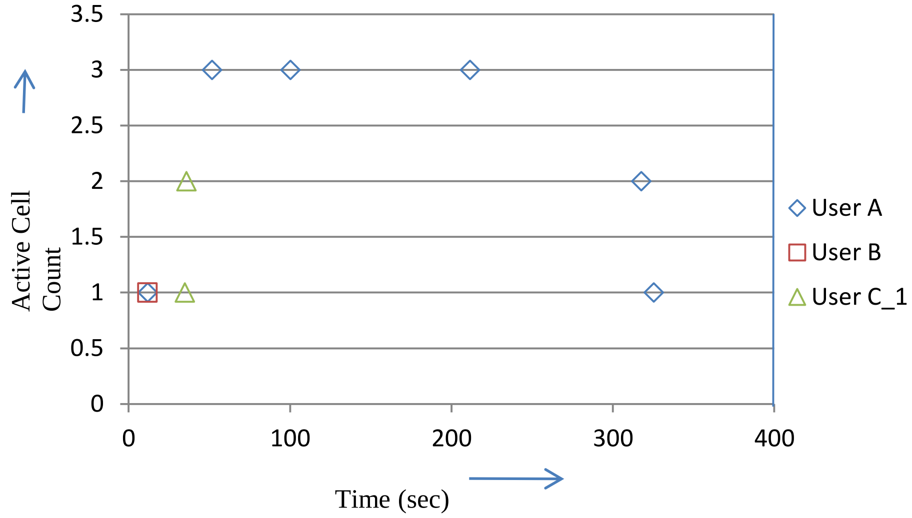

Figure 9.2 UEs Active Cell Count for Soft Handoff

Figure 9.3 and figure 9.4 shows the statistic which is threshold set for enter in the active set of user. During hard handoff as shown in figure 9.3 initially user A connected to node_0 after which it starts approaching node_3 and node_4, it makes RNC to proceed procedure of handoff by RNC for user A because user A receive high pilot channel from these nodes start at time 70 sec than node_0. For hard handoff user A break connection to node_0 at time 84 sec and connected to node_3 as pilot channel of this node is higher than node_0 and for soft handoff user A connected to node_3 with these cells added to their active set at 81 sec with pilot channel of 5.9db. At 161 sec of time hard handoff break connection to node_3 and connected to node_5 having pilot channel 13.1db higher than node_3, which is added to active set for soft handoff replacing node_0 at time 159 sec with 12.9 db.

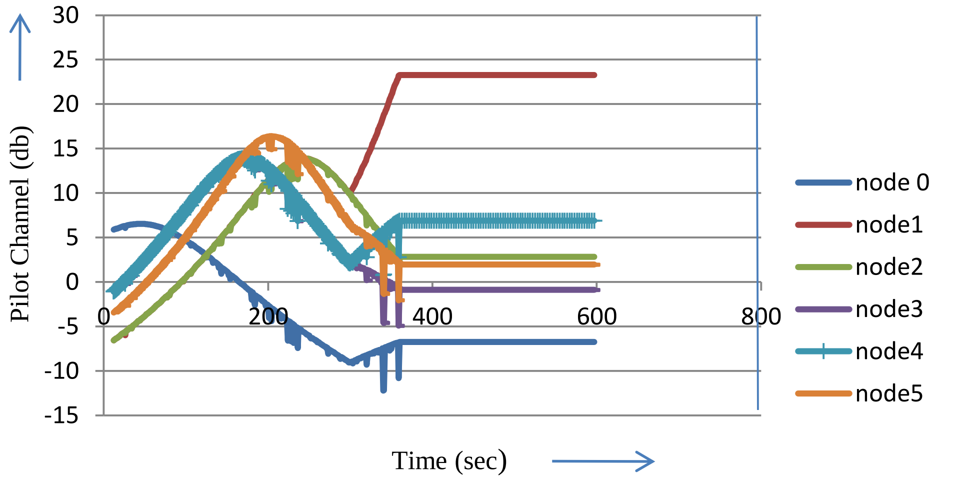

Figure 9.3 Pilot Channel (db) of user A Active Set for Hard Handoff

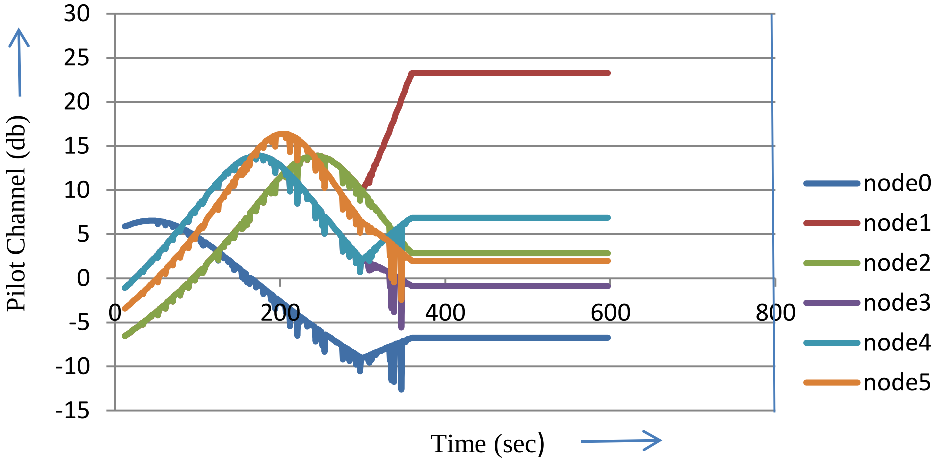

Figure 9.4 Pilot Channel (db) of user A Active Set for Soft Handoff

Now A close to node_1 and node_2, at 236 sec node_1 and node_2 added to active set of A during soft handoff by replacing node_3 and node_4 as their pilot channel are less than these nodes. At same time during hard handoff as pilot channel of node_5 drops and node_1 has 2db more pilot channel so A connected to node_1 and stay with it as its pilot channel is highest than other nodes as shown in figure 9.4. Similarly for soft handoff node_1 and node_2 having 2db more pilot channel than node_5 added to active set by replacing node_4 and node_5 and connected to node_1 having highest pilot channel of 23db. It is concluded that nodes are added to active set based upon pilot channel, handoff done with node_b having highest pilot channel of active set for soft handoff and for hard handoff done with node_b having higher pilot channel then old node_b.

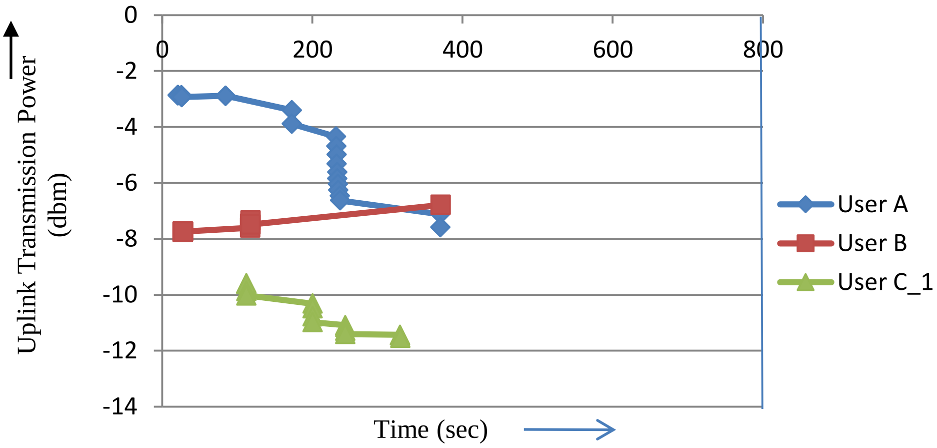

Figure 9.5 Uplink Transmission Power (dbm) of UEs for Hard Handoff

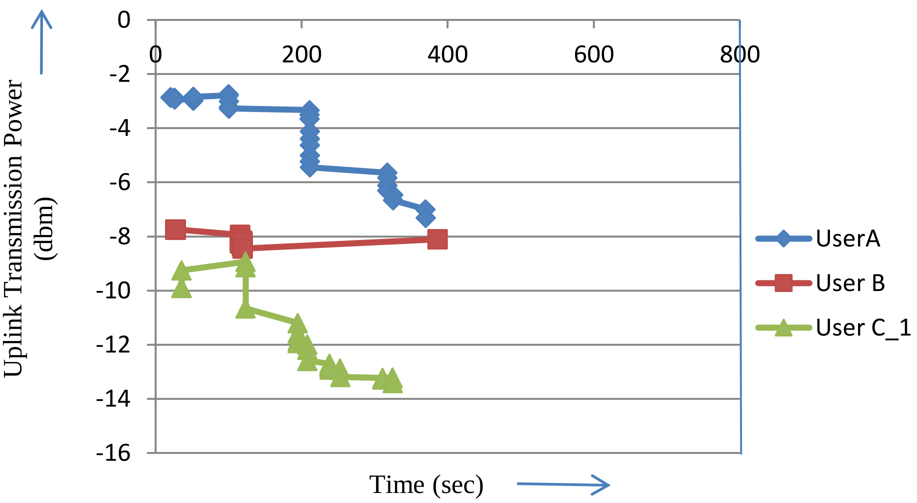

Figure 9.6 Uplink Transmission Power (dbm) of UEs for Soft Handoff

Figure 9.5 and figure 9.6 shows power used by UE to transmit packets over physical channel. It is observed from the figure 9.5 that during hard handoff initially uplink transmission power of A is -2dbm as it moves along trajectory it decreases gradually with time, at 173 sec power decreases sharply to -4dbm. Further at231 sec from -4.3dbm it falls suddenly up to -6.2dbm and further decreases to -8dbm. It means A required less transmission power to sent packets to node_b's. User B required more uplink transmission power as it increases with its trajectory, starting from -8dbm to -6.7dbm. Similarly user C_1 requires very less power as compared to other user. It starts with -10dbm at 112 sec and complete with -11dbm at 316 sec. During soft handoff from fig 4.12 A starts with -2dbm and first falls at 100 sec to -2.7dbm and at 211 sec it falls sharply from 3.3dbm to -5dbm and further falls to -6dbm. User B requires less power during soft handoff starts with -8dbm which decrease gradually and at 115 sec it increases from -7.9dbm to -8dbm. C_1 starts with -10dbm transmission power and increases to -8.9dbm at 123 sec from where it sharply falls to -10.6dbm and decrease gradually-13dbm. Results show, less transmission power required by UEs to send packets to node_b's during soft handoff as compared to hard handoff or soft handoff improves uplink transmission power during handoff.

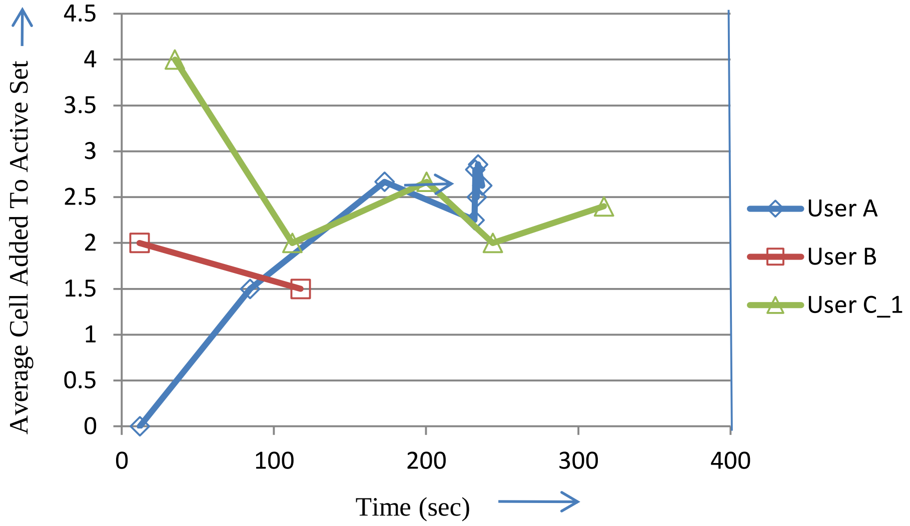

Figure 9.7 Average Cell Added To Each UEs Active Set for Hard Handoff

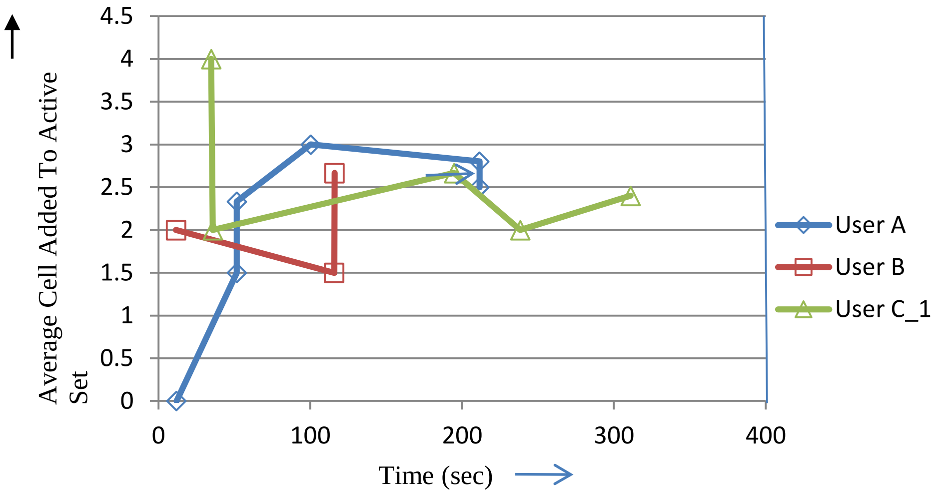

Figure 9.8 Average Cell Added To UEs Active Set for Soft Handoff

Figure 9.7 and 9.8 shows statistic reports the cell IDs of the cells that are added to the active set of the surrounding UE throughout the simulation initially and during handovers. Each cell ID information is recorded at the simulation time when the addition takes place. Figure 9.7 and figure 9.8 shows the no. of cells or node_b added to active set of each UE respectively. During hard handoff as shown in figure 3.4 initially user A connected tonode_0 having single cell in its active set after which it starts approaching node_3 and node_4, it starts procedure of handoff by RNC for A. For hard handoff user A break connection to node_0 and connected to node_3 and for soft handoff these cells added to their active set after 50 sec of cells detection. At 100 sec hard handoff break connection to node_3 and connected to node_5 which is added to active set for soft handoff replacing node_0, at approximately 210 sec node_1 and node_2 added to active set by replacing node_3 and node_4 as soft handoff active set is set to 3, but during hard handoff connection with node_1 is established after breaking connection to node_5, then user A turn towards node_1 and break connections to node_2 and node_5 during soft handoff. Five cells added to active set of user A during soft handoff and three cells added during hard handoff. Similarly for user B two cells added to its active set during soft handoff and one cell during hard handoff. For user C_1 four cells added to its active set during both handoffs.

X. CONCLUSION

UMTS system supports different handoffs especially hard handoff and soft handoff. Our work presents UMTS technology architecture, QoS metrics of hard handoff and soft handoff of UMTS network system. It is concluded that soft handoff improves the link level performance and system level performance of UMTS system. Soft handoff support mobility of users without connection break as user always connected to at least one base station at a time during soft handoff. Soft handoff sent data packets with less uplink transmission power than hard handoff.

REFERENCES

[1] 3rd Generation Partnership Project, Technical Specification Group RAN, Working Group 4 (TSG RAN WG4), “UE Radio transmission and reception (FDD)”, 3G TS 25.103, V2.0.0, September 1999.
[2] 3rd Generation Partnership Project, Technical Specification Group RAN, Working Group 2 (TSG RAN WG2), “General UMTS Architecture”, 3G 23.101 v3.0.1, April 1999.
[3] 3rd Generation Partnership Project, Technical Specification Group RAN, Working Group 2 (TSG RAN WG2), “Radio Resource Control (RRC) protocol specification”, 3G TR 25.331, V3.14.0, Release 99, March 2003.
[4] 3rd Generation Partnership Project, Technical Specification Group RAN, Working Group 2 (TSG RAN WG2), “Radio Resource Control (RRC) protocol specification”, 3G TR 25.331, V3.14.0, Release 99, March 2003.
[5] Castro. J.P. The UMTS Network and Radio Access Technology, “Air Interface Techniques for Future Mobile Systems”. Wiley, John &Sons, Incorporated: UK, May 2001.
[6] Chen Yue, "S Soft Handover Issues in Radio Resource Management for 3G WCDMA Networks", Department of Electronic Engineering, Queen Marry, University of London, 2000.
[7] Cuny. R and Lakaniemi. A, "VoIP in 3G networks: An end-to-end Quality of Service analysis."
[8] Dahlman. E, Knutsson. J, Ovesjo. F, Persson. M and Roobol. C, “WCDMA- The Radio Interface for Future Mobile Multimedia Communications,” Vehicular Technology, IEEE Transactions on, Vol.47, No.4, pp. 1105-1118, Nov. 1994.
[9] Dahlman. E and Bening. P “WCDMA –the Radio Interface for Future Mobile Multimedia Communications”, IEEE Trans. on Vehicular Technology, Vol 47, No 4, November 1998.
[10] Garg, V.K., and Wilkes, J.E, “Interworking and interoperability issues for North American PCS”, IEEE Communications Magazine, Vol 34, No 3, pp. 94-99, Mar 1996.
[11] Garg. Vijay K and Oliver T. W. Yu, “Integrated QoS Support in 3G UMTS Networks”, IEEE paper, 2000.
[12] Grandell. J and Salonaho. O, “Closed-Loop Power Control Algorithms in Soft Handover for WCDMA Systems,” Proceedings of ICC’2001, vol. 3, pp. 791-795, 2001.
[13] Holma. H and Toskala. A, WCDMA for UMTS, Radio Access For Third Generation Mobile Communications, John Wiley & Sons, LTD. 2000.
[14] Hong. S. J and Lu. I. T, “Soft Handoff Algorithm Parameter Optimization in Various Propagation Environments”, IEEE VTC’01, pp. 2549-2553, 2001.
[15] Hu. F, Sharma. N.K., “Priority-determined multiclass handover scheme with guaranteed mobile QoS in wireless multimedia networks”, in Proc. IEEE Transactions on Vehicular Technology, Vol. 53, Issue 1, Jan., , pp 118 –135, 2004.
[16] Jansen M. G. and Prasad. R, “Capacity, Throughput, and Delay Analysis of a Cellular DS CDMA System with Imperfect Power Control and Imperfect Sectorization”, IEEE Trans. Veh. Technol., vol. VT-44, no. 1, pp: 67-75, Feb. 1995.
[17] Juntti. M and Latva-aho. M, “Multiuser receivers for CDMA systems in Rayleigh fading channels”, IEEE Trans. Vehic. Tech., 2000.
[18] Kari. S, Mika. J, Jaana. S. L, Achim. W, “Soft Handover Gains in A Fast Power
[19] Controlled WCDMA Uplink”, IEEE VTC’99, pp. 1594-1598, 1999.
[20] Kim. D. K and Sung. D. K, “Characterization of soft handoff in CDMA systems,” IEEE Trans. Veh. Technol., vol. 48, no. 4, pp. 1195–1202, Jul. 1999.
[21] Knutsson. J, Butovitsch. J, Persson .M and Yates. R, “Evaluation of Admission Control Algorithms for CDMA System in a Manhattan Environment”, Proceedings of 2nd CDMA International Conference, CIC’97, pp. 414-418, Seoul, South Korea, October 1997.
[22] Laukkanen Jussi “UMTS Quality of servive concept and Architecture”, University of Helsinki, 4-5-2000.
[23] Lee. C and Steele. R, “Effects of soft and softer handoffs on CDMA system capacity”, Vehicular Technology, IEEE Transactions on, Vol. 47, No. 3, pp. 830-841, Aug. 1998.
[24] Liu. Z. P; Wang. Y. F and Yang. D. Ch, “Effect of soft handoff parameters and traffic loads on soft handoff ratio in CDMA systems,” Communication Technology Proceedings, 2003. ICCT International Conference on, Vol. 2, pp. 782-785, 2003.
[25] Marichamy. P,barti. S. Chakra and Maskara. S. L, "Overview of Handoff Schemes in Cellular Mobile Networks and their Comparative Performance Evaluation", IEEE 1999.
[26] Matusz. P, Machan. P, and Wozniak. J, “Analysis of profitability of inter-system handoffs between IEEE 802.11b and UMTS,” in Proceedings of the 28th Annual IEEE International Conference on Local Computer Networks, pp. 210-21, 2003.
[27] Mihailescu. C, Lagrange. X and Godlewski. Ph, “Soft handover analysis in downlink UMTS WCDMA system”, Mobile Multimedia Communications, (MoMuC '99) IEEE International Workshop on, pp. 279 –285, 1999.
[28] Narrainen. R. P and Takawira. F, “Performance analysis of soft handoff in CDMA cellular networks”, Vehicular Technology, IEEE Transactions on, Vol. 50, Issue. 6, pp. 1507-1517, Nov. 2001.
[29] Ojanpera. T, Prasad. R, and Harada. H, “Qualitative comparison of some multiuser detector algorithms for wideband CDMA,” Proc.IEEE Vehicular, Tech. Conf., 1, pp. 46-50, 1998.
[30] OPNET™ 14.5 online help documentation, 2009.

[31] Saad. E. M, Ghandour. O. M. and Jehan. M.K, "Evaluation of QoS in UMTS Backbone Network Using Differentiated Services", 25th National Radio Science Conference (NRSC), Egypt, 2008.
[32] Saussy. G, "Key business challenges in the 3G network evolution", International Forum on 4th Generation Mobile Communications, May 2002.
[33] Shinagawa. N, Kobayashi. T, Nakono. K, and Sengoku. M, "Tele traffic evaluation between a switch and base stations in cellular systems with multiple-connection capability for soft handoff", in Proc. IEEE Vehicular Technology Conf. (VTC), Amsterdam, The Netherlands, vol. 2, pp. 1243–1247, 1999.
[34] Soh Wee-Seng and Kim Hyong. S, "QoS Provisioning in Cellular Networks Based on Mobility Prediction Techniques", IEEE comms Magazine, Vol 41, No. 1, pp. 86-92, January 2003.
[35] Stojmenovic Ivan, Handbook of Wireless Networks and Mobile Computing, a wiley-interscience publication john wiley and sons, inc, 2002.
[36] Viterbi, Viterbi. A. M, Gilhousen. K. S, and Zehavi. E, "Soft handoffs extends CDMA coverage and increase reverse link capacity", IEEE J. Select. Areas Communications, Vol. 4, No. 8, pp. 1281-1288, 1994.
[37] Walke. B, Seidenberg. P, and Althoff. M.P, "UMTS – The Fundamentals", 1st edition, John Wiley, 2003.
[38] Wong Daniel, Lim Teng Joon, "Soft handoffs in CDMA mobile systems", IEEE Personal Communications, vol. 4, no. 6, December 1997.
[39] Zhang. D, Wei. G, Zhu. J, "Performance of Hard and Soft Handover for CDMA Systems", IEEE Vehicular Technology Conference, pp. 1143-1147, 2002.