International Journal of Advanced Research in Computer Engineering & Technology (IJARCET)
Volume 4 Issue 9, September 2015

ADAPTIVE MODULATION TECHNIQUES FOR CAPACITY IMPROVEMENT OF BER IN WCDMA

Alumona T.L[1], Onoh G.N[2], Ezeagwu C.O[3], Okeoma S.C[4].

Abstract—**Due to the growing demand for high bandwidth and high speed information transfer in the communication industry in the present day society, it becomes inevitable that a network has to be fast to meet up to an extent of demand from different communication traffics and services. This has raised up research issues of adaptive modulation for the achievement of this purpose. This paper examines the benefits of using adaptive modulation in terms of spectral efficiency and probability of bit error in real radio networks environment. In channels that fluctuate dynamically over time, systems that are based upon the conventional methods of fixed modulation formats do not perform well. Adaptive modulation provides many parameters that can be adjusted relative to the channel fading, including data rate, transmit power, instantaneous BER, symbol rate, and channel code rate or scheme.**

Index Terms—**adaptive modulation techniques,bandwidth, modulation, , network, WCDMA**

I. Introduction

In recent years, there has been an increasing demand in mobile communication services with limited spectrum bandwidth. Wide- band Code Division Multiple Access (W-CDMA) is a spread spectrum technique that allows a large number of users to share access to a single communication channel by encoding their data with a special pseudo noise (PN) code for each channel [1], W- CDMA cellular systems use a form of direct sequence CDMA (DS- CDMA). Third generation systems use W-CDMA as the carrier modulation scheme [2]; this is because of the many advantages that it offers.

W- CDMA offers many advantages which include jam resistance, privacy and flexibility – also allowing a greater cellular spectral efficiency than 2G systems [2]. CDMA has been considered and recognized as a viable alternative to both FDMA and TDMA [3]. W-CDMA schemes have many advantages over FDMA and TDMA but these advantages are hindered by the increasing interference caused by other active terminals, since all signals in the W-CDMA system share the same transmission bandwidth. Blocking occurs when the tolerance limit to interference is exceeded, hence in W-CDMA, the level of interference is a limiting factor [3]. Consider a receiver and two terminals (transmitters) with one closer to the receiver and the other farther away. If they transmit simultaneously at equal powers, then the receiver will receive more power from the nearest transmitter. Since one's transmitted signal is the other's noise, the signal-to-noise ratio (SNR) for the farther transmitter is much lower. If the nearest transmitter transmits a signal of magnitude higher than the farther transmitter, then the SNR for the latter may be below detect ability and may as well not transmit. This effectively distorts the communication channel.

This problem is commonly solved by dynamic modulation and dynamic output power adjustment of the transmitters [3]. That is, the nearest transmitter uses less power and higher order modulation techniques so that the SNR for all transmitters at the receiver is roughly the same. This sometimes can have a noticeable impact on hand set battery life, which varies depending on distance from the base station.

II. Problem Statement

This paper examines the benefits of using adaptive modulation in terms of spectral efficiency and probability of bit error in a real radio network environment.
In channels that fluctuate dynamically over time, systems that are based upon the conventional methods of fixed modulation formats do not perform well.
Adaptive modulation provides many parameters that can be adjusted relative to the channel fading, including data rate, transmit power, instantaneous BER, symbol rate, and channel code rate or scheme. In this paper, a systematic study on the increase in spectral efficiency obtained by optimally varying combinations of the modulation formats for a real radio environment is provided, it has been assumed, that the transmitter has a perfect knowledge of the channel conditions and the resulting adaptive modulation system is subject to an average BER constraint. Simulations show how adaptively changing the modulation schemes improves the performance of the system by meeting a BER constraint over a range of SNR.

III. Objectives of the research

To enhance the quality of a communication system, there is a need to keep the bit error of aW- CDMA network at threshold value by finding the modulation techniques, transmitter power Levels, given a number of terminals transmitting

Manuscript received Sep, 2015.
Alumona Theophilus L, *Department of Electronic & Computer Engineering, Nnamdi Azikiwe University Awka, Anambra, Nigeria,*
Onoh G.N, *Electrical Engineering Department, Enugu State University of Science and Technology Enugu State Nigeria.*
Ezeagwu Christopher O, *Department of Electronic & Computer Engineering, Nnamdi Azikiwe University Awka, Anambra, Nigeria,*
Okeoma Samuel C, *Department of Electronic & Computer Engineering, Nnamdi Azikiwe University Awka, Anambra, Nigeria,*

ISSN: 2278 – 1323

simultaneously and changing the modulation techniques simultaneously as well.

The specific objectives of the research are:

(1) To evaluate the effects of noise on the bit error rate and throughput on a W- CDMA network.

(2) Evaluation of Bit Error rate of QAM and QPSK system versus signal to noise ratio (SNR) are used to evaluate system for adaptive modulation for capacity improvement.

IV. Summary of Related Research Efforts

A. Adaptive Modulation and Data Rate

In [4], the author defines an Adaptive modulation in cognitive radio as: "an intelligent wireless communication system that is aware of its environment, and uses the understanding-by-building methodology to learn from the environment and adapt to statistical variations in the input stimuli.

B. Effective Packet Length and data rate:

In [5], their work presents a mathematical technique for determining the optimum transmission. The throughputs defined as the number of bits per second correctly received. Trade-offs between the throughput and the operation range are observed, and equations are derived for the optimal choice of the design variables. These parameters are SNR dependent and can be adapted dynamically in response to the mobility of a wireless data terminal. They also looked at the joint optimization problem involving all the design parameters together. They found that not all the three parameters (b, SNR, L) need to be adapted simultaneously: in the received SNR per symbol stays at some rate so that the received SNR per symbol stays at some preferred value.

They also varied received power by changing the distance between the transmitter and receiver. Finally, they gave a characterization of the optimal parameter values as functions of received SNR.

The thesis work of [6] examined some of the variables affecting throughput and they include; packet size, transmission rate, received signal power, etc. he looked at the effect of transmission rate and packet size on throughput. He also looked at how the transmission rate and packet size can optimize the throughput jointly.

His analysis involved forward error correction which theoretically should improve the throughput and also when there is no forward error correction. The analysis was also performed involving BCH codes for comparison of results to draw a more general conclusion; his work did not take any particular wireless system into account.

His result is a mathematical technique for determining the optimum transmission rate and packed size as a function of other variables. He also found out that they key to maximizing the throughput rate is maintaining the signal to noise at an optimum level.

An early work of [7], introduce variable rate QAM. The transmitter varies the signal constellation size from 1bit/symbol corresponding to BPSK, 2bits/symbol for QPSK and 6bits/symbol star for 64-QAM. In a good quality channel, the constellation size is increased, and as the channel quality become worst, that is, as the receiver enters a deep fade, the constellation size is decreased to a value, which provides an acceptable BER. Two choices of implementation can be applied; to keep constant of one parameter and varying the other parameter. Specifying a required BER value leads to varying data throughput and vise versa. The work also highlights two different types of switching criteria to control the modulation modes, Received Signal Strength Indicator (RSSI) system and error detector switching system. RSSI system uses SNR values corresponding to the BER of interest as the switching thresholds while the later system use the channel coder to monitor the channel quality. Simulation results showed the performance improvement over fixed modulation and comparisons of the two switching systems. It is observed that RSSI typically offering a slightly higher number of bits/symbol at low SNRs for some BERs. This is due to the RSSI switching system's ability to select a lower number of levels before any errors occurred. RSSI is also more attractive in term of implementation complexity because no additional BCH codec is needed.

According to [8], the author examined switching system as the channel state information (CSI) which specified the channel quality. SNR based CSI corresponding to RSSI system was compared with error-based CSI corresponding to error detector switching system. SNR based CSI adapts with a faster rate, but relies on the computation of adaptation or switching thresholds that may be inaccurate. Accuracy of the threshold mechanism increases by taking into account higher order statistics of SNR than just the mean. Studies on varying combination of parameters also attract a great interest. In the work of [9] produce trellis-coded adaptive MQAM. Analytical and simulation results shows that the new simple 4-state trellis-coded adaptive MQAM achieves 3-dB effective coding gain relative to un-coded adaptive M-QAM and 3.6 dB for 8-state trellis. Compared with traditional trellis codes and fixed-rate modulation, the new scheme showed more than 20 dB power savings.

V. Modulation Schemes in Wireless Systems

Quadrature Phase Shift Keying (QPSK) is a digital modulation technique. Quadrature Phase Shift Keying (QPSK) is a form of Phase Shift Keying in which two bits are modulated at once, selecting one of four possible carrier phase shifts (0, Π/2, Π, and 3Π/2). QPSK perform by changing the phase of the In-phase (I) carrier from 0° to 180° and the Quadrature-phase (Q) carrier between 90° and 270°. This is used to indicate the four states of a 2-bit binary code. Each state of these carriers is referred to as a Symbol [4].

Quadrature Phase-shift Keying (QPSK) is a widely used method of transferring digital data by changing or modulating the phase of a carrier signal. In QPSK digital data is represented by 4 points around a circle which correspond to 4 phases of the carrier signal. These points are called symbols. Fig 1. shows this mapping.

ISSN: 2278 – 1323

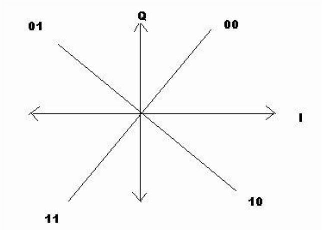

Fig 1: QPSK diagram showing how 4 different binary codes are transmitted

VI. M-ARY QUADRATURE AMPLITUDE MODULATION (QAM)

The Modulation equation for QAM is a variation of the one used for PSK. The generalized PSK allows changing the Amplitude and the Phase. In PSK all points lie on a circle so the I and Q values are related to each other. PSK signals are constant envelops because of this; all points have the same amplitude. If we allow the phase and amplitude to change from symbol to symbol, then we get a modulation called quadrature amplitude modulation (QAM). It can be considered a linear combination of two DSB-SC.so it is an AM and a PM modulation at same time.

$$s_m(t) = \sqrt{\frac{2E_s}{T_s}}\cos(\theta(t)\cos(2\pi f c t) - \sqrt{\frac{2E_s}{T_s}}\sin(\theta(t)\sin 2\pi f c \text{—} 1$$

This equation can be used to create an hybrid type of modulation that varies both in amplitude and the phase. When M=16,we have 16 symbols, each representing a four bit word. We can lay these out in a circle but they would be too close an error rate is likely to be high.

In 16QAM, we vary not just the phase of the symbol but also the amplitude. In PSK, all symbols sat on a circle so they all had the same amplitude.

Table 1 – Measured Data From BTS 1

					QPSK Modulation				
Distance(km)	Class	Site ID	Freq(MHz)	TX power (dbm)	Antenna tilt	Rxav	Antenna Height	Latitude	Longitude
100	2G&3G	IMO473	2116.4	19	2	-62	30	7.32006	5.45109
200	2G&3G	IMO473	2116.4	19	2	-64	30	7.32672	5.46606
300	2G&3G	IMO473	2116.4	19	2	-65	30	7.25217	5.45244
400	2G&3G	IMO473	2116.4	19	2	-66	30	7.27684	5.43247
500	2G&3G	IMO473	2116.4	19	2	-67	30	7.24378	5.43256
600	2G&3G	IMO473	2116.4	19	2	-67	30	7.11419	5.32464
700	2G&3G	IMO473	2116.4	19	2	-68	30	7.17894	5.33116
800	2G&3G	IMO473	2116.4	19	2	-69	30	7.12684	5.58244
900	2G&3G	IMO473	2116.4	19	2	-71	30	7.11753	5.55553
1000	2G&3G	IMO473	2116.4	19	2	-72	30	7.16613	5.54977
1100	2G&3G	IMO473	2116.4	19	2	-77	30	7.04823	5.59538
1200	2G&3G	IMO473	2116.4	19	2	-78	30	7.09344	5.59775
1300	2G&3G	IMO473	2116.4	19	2	-79	30	7.09883	5.61931
1400	2G&3G	IMO473	2116.4	19	2	-77	30	7.06436	5.60014
1500	2G&3G	IMO473	2116.4	19	2	-79	30	7.07995	5.64786

Table 2: Measured Data from BTS2

					QPSK Modulation				
Distance(km)	Class	Site ID	Freq(MHz)	TX power (dbm)	Antenna tilt	Rxav	Antenna Height	Latitude	Longitude
100	2G&3G	OWERRI ROAD	2116.4	44.1	4	-51	30	7.02083025	5.50538802
200	2G&3G	OWERRI ROAD	2116.4	44.1	4	-53	30	7.03044452	5.42936525
300	2G&3G	OWERRI ROAD	2116.4	44.1	4	-57	30	7.04589247	5.48702654
400	2G&3G	OWERRI ROAD	2116.4	44.1	4	-58	30	6.99610813	5.38278138
500	2G&3G	OWERRI ROAD	2116.4	44.1	4	-65	30	7.19702877	5.4248618
600	2G&3G	OWERRI ROAD	2116.4	44.1	4	-67	30	7.15152713	5.39435815
700	2G&3G	OWERRI ROAD	2116.4	44.1	4	-69	30	7.02544652	5.48999718
800	2G&3G	OWERRI ROAD	2116.4	44.1	4	-70	30	7.04208203	5.51274549
900	2G&3G	OWERRI ROAD	2116.4	44.1	4	-72	30	6.9980316	5.48594597
1000	2G&3G	OWERRI	2116.4	44.1	4	-74	30	7.11161477	5.91224577

ISSN: 2278 – 1323

		ROAD							
1100	2G&3G	OWERRI ROAD	2116.4	44.1	4	-79	30	7.14836158	5.65260958
1200	2G&3G	OWERRI ROAD	2116.4	44.1	4	-82	30	7.27480299	5.6326357
1300	2G&3G	OWERRI ROAD	2116.4	44.1	4	-86	30	7.04044422	5.3053065
1400	2G&3G	OWERRI ROAD	2116.4	44.1	4	-88	30	7.33155667	5.4865555
1500	2G&3G	OWERRI ROAD	2116.4	44.1	4	-94	30	7.25213979	5.7687578

Tables 1 and 2 show sample data of the average of the recorded received signal power against respective distances measured using QPSK modulation.

VII. Bit Error Rate and Adaptive Modulation in WCDMA System

A generic model of DSSS W-CDMA is shown in figure 2 and it is simulated using QPSK then followed by QAM. QPSK and QAM are chosen in this thesis because they are the primary candidates to deliver higher data rate for High Speed Downlink Packet Access (HSDPA), an extension of 3G networks. The simulation is done under noise and multipath fading channel using MATLAB 7.5. R2007bunits.

VIII. Simulation using Simulink

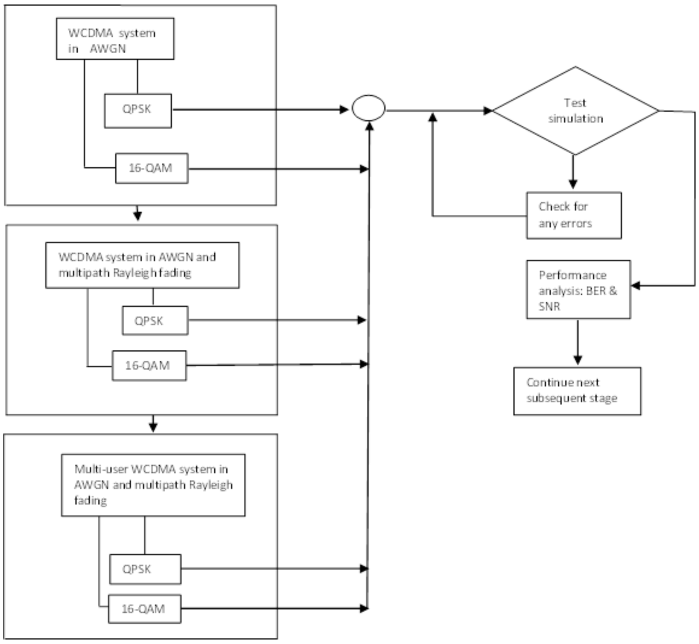

Figure 2: Simulation flow chart for W-CDMA system models used in Simulink

Two types of simulation have been chosen to study the performance of modulation techniques of WCDMA subjected to multipath fading in the channel. The paper begins with simulation using simulink. Simulink is a software package that has the capabilities to model, simulate, and analyze dynamic
systems whose outputs and states change with time. Simulink can be used to explore the behavior of a wide range of real-world dynamic systems making it a suitable computer software to study the performance of modulation techniques under multipath fading. Simulating a dynamic system is a two-step process with simulink. First, a graphical model of the system is simulated, using the simulink model editor. The model depicts the time-dependent mathematical relationships among the system's inputs, states, and outputs. Then, simulink uses information entered into the model to perform the simulation.

Figure 2 above describes a simulation flow chart for W-CDMA system models used in Simulink for this work.

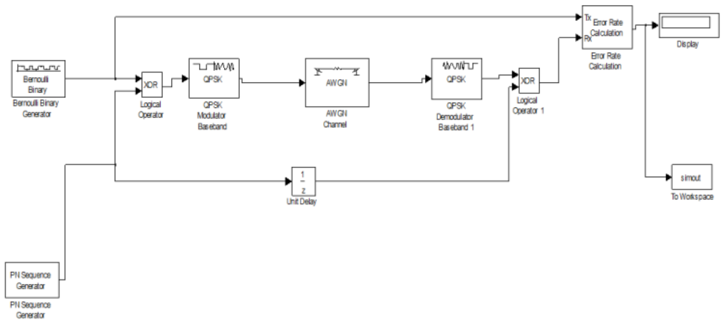

FIGURE 3: W-CDMA MODEL USING QPSK MODULATION TECHNIQUE IN AWGN CHANNEL

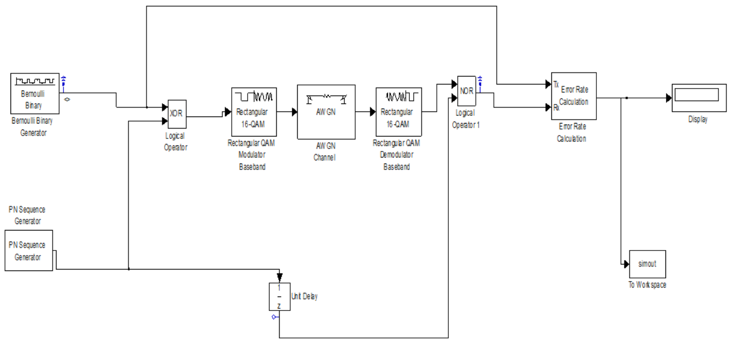

FIGURE 4: W-CDMA MODEL USING 16-QAM MODULATION TECHNIQUE IN AWGN CHANNEL

IX. Performance Analysis of QPSK Modulation Technique of WCDMA in AWGN

Table 3: simulation result for evaluation on BER vs. SNR for 2-ray AWGN channel for 1 user when the number of data is 200,000

ISSN: 2278 – 1323

Signal-to-Noise Ratio (E_bN_0	No. of Error	Bit Error Rate (BER)
0	15615	7.807500e-002
1	11334	5.667000e-002
2	7520	3.760000e-002
3	4484	2.242000e-002
4	2489	2.244500e-002
5	1205	6.025000e-003
6	462	2.310000e-004
7	165	8.250000e004
8	39	1.950000e-004
9	2	1.000000e-005
10	1	5.000000e-006

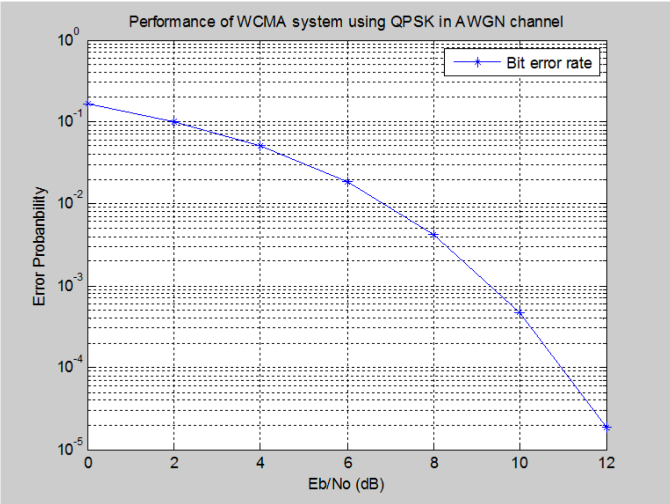

Figure 5: Performance of WCDMA system using QPSK in AWGN channel.

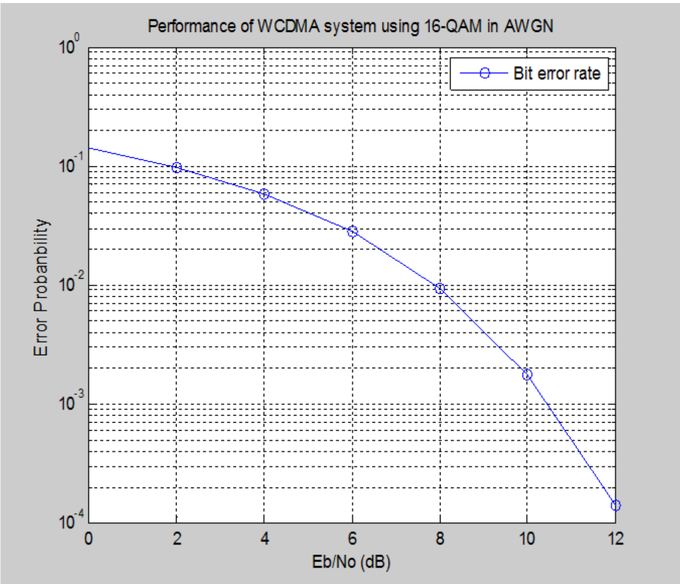

Figure 5: Performance of WCDMA system using QPSK in AWGN channel.

The block diagram, shown in Figure 7 reveals the functioning of the link adaptation mechanism (including both adaptive modulation and power control). The transmitter chooses a suitable link characteristic based on the command it receives through the feedback channel. The flowchart shown in Fig. 3.4 depicts the operation of the adaptive modulation module. The function of the transmitter is always to enhance the spectral efficiency subject to the BER constrains. While working with adaptive modulations, one of the critical issues is to find out a suitable means to decide upon the best-suited modulation scheme for the prevailing channel conditions. The received SINR and path loss exponent is used as the channel metric to decide on the modulation type (QAM and QPSK modulation) .If the path loss exponent is small choose QPSK and when it is large Choose QAM. There also exists a SINR target for satisfying the target BER of which depends on traffic classes. The next problem is to decide on the range of SINR values that can be used for modulation scheme

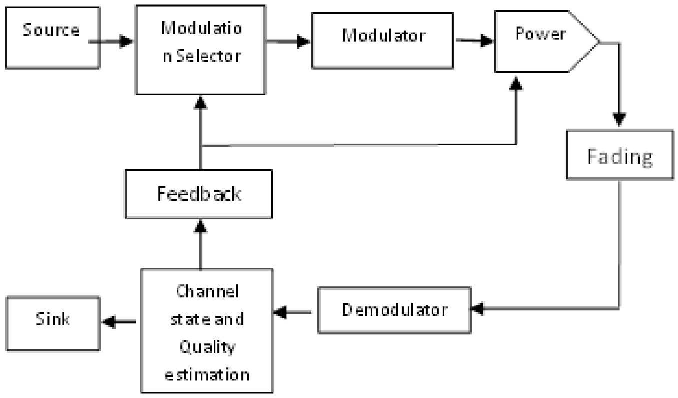

Fig. 7 Block diagram link adaptation mechanism

X. Conclusion

a. Deductions

Both simulation using simulink and m-file shows that each QPSK and 16-QAM modulation technique in AWGN channel has good performance when it is compared under multipath Rayleigh channel. Also, the performance of QPSK and 16 –QAM degrades when the channel is subjected to multipath fading with increasing value of Doppler shift (Hz). In other words, it performs, poorly as the speed of mobile terminal is increased. Moreover, the system performs badly as the number user is increased. Comparison between QPSK and 16-QAM modulation schemes shows that 16-QAM performs very poorly in both AWGN and AWGN with multipath fading channel. The simulation of 16-QAM modulation technique using m files cannot be done because it is suspected that the variation of amplitude with phase cause in the constellation of 16-QAM signal. Thus, analysis for 16-QAM can only be done in Simulink.

XI. References

[1] Proakis, G.J. "*Digital Communication" fourth Edition, McGraw-hill International Editions 2001.*

[2] Rajeshree Raut, Priti Subramanium and Kavita Bramahankar: *Adaptive Coding Techniques to Improve BER in OFDM system, International Journal of Image Processing and Vision Sciences (IJIPVS) ISSN(Print)2278 – 1110, Vol-1 Iss-3,4,2012*

ISSN: 2278 – 1323

[3]Gunnarsson, F. “Power Control in Wireless Networks: characteristics and fundamentals, “in Wireless Communications Systems and Networks, M. Guizani, Ed. New York: Plenum Press, pp. 179-20 (2004).

[4] Goodman, d and Mandayam, N. “Network assisted power control for wireless data, “Mobile Network. And Appl., vol. 6, no. 5, pp. 409-418.

[5] Sklar, B. Digital Communications: Fundamentals and applications, fundamental and Applications – 2nd edition (2001).

[6]Akl, R and Parvez, A. ‘Impact of Interference Model on capacity in CDMA cellular Networks’ Proceedings of SCI 04. Communication and Network Systems, Technologies and Applications, 3:404-408 (2004).

[7]Julian Cheng, Norman, C. Beaulieu, “Accurate DS-CDMA Bit-Error Probability calculation in Rayleigh fading”, IEEE Transactions on Wireless Communications, Vol 1, No. 1, January 2002.

[8] Akl, R et.al ‘Mobility-based CAC Algorithm for Arbitrary Traffic Distribution in CDMA Cellular System’ IEEE Trans. Veh. Technol., 54:639-651 (2005).

[9]Proakis, G.J. “Digital Communication” fourth Edition, McGraw-hill International Editions (2002).
[10] Huawei Technologies Co., Ltd, “Network Preliminary Proposal for Erbil CDMA WLL Project”, 2003

[11] Coperation, , “The Wireless Network Planning Report For Dalyasat Project”, 2006.

ISSN: 2278 – 1323