ENHANCED WCDMA POWER CONTROL MECHANISM USING KALMAN FILTERING AND LINEAR QUADRATIC GAUSSIAN APPROACH

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Abstract— A good power control algorithm is very essential in a Wideband Code Division Multiple Access (WCDMA) system. This is to prevent Near - Far effect or Multi - Access Interference (MAI) and its associated effects, which include degradation of channel capacity and signal quality, as well as significant drain of the user equipment (UE) battery power. To solve these problems, there is the need for an effective and efficient power control mechanism to compensate for the fading fluctuations in the transmit power level of the mobile stations (MS) such that the signal power from multiple UE's (Near or far) is made equal at the Base Station**.** The conventional power control algorithm, based on SIR, may lead to positive feedback or power escalation when the far away MS increases its transmit power to compensate for the interference from the near MS. This paper proposes a method, based on predicting the state of the transmission channels to develop an improved power control mechanism in WCDMA systems. The proposed method uses Kalman filtering and Linear Quadratic Gaussian (LQG) control for channel prediction. Some conventional methods of power control in WCDMA such as Fixed Step size method, Quantized Step size method and Ideal Method are examined. The proposed method is then compared with the conventional methods using MATLAB. Analysis of the simulations show that the proposed method recovers faster from deep fades and provides a more steady performance than the conventional methods.

Keywords**: Power control mechanism, Kalman Filtering, Linear Quadratic Gaussian**

I. Introduction

In mobile communication systems, power control is used to ensure that power transmission from and to all entities in a system is sufficient to sustain the least Signal - to - Interference Ratio (SIR) for all connections. By using a perfect power control mechanism, every user will transmit with the minimum power to meet its lowest SIR requirement which, in turn, translates to reduced interference in the system [1]. Power control has a significant role in maintaining the communication link quality, under fading and interference conditions. It is responsible for ensuring that transmit power is kept at minimal level while the signal to interference plus noise ratio (SINR) target is achieved [2].

Furthermore, since WCDMA is interference-limited multiple access system, power control is an efficient way to minimize co-channel interference and solve the near-far field problem, thereby enhancing the system capability, and achieving higher data rate [3]. Power control is probably the most critical features of WCDMA, especially in the uplink direction, without which, a single mobile with a very strong signal could block a whole cell [4]. Efficient power control is, therefore, very important for the effective performance of WCDMA system. Power control is needed to minimize interference in the system and, given the nature of the DS-CDMA (in which all signals are transmitted using the same frequency at the same time), a good power control algorithm is essential.

Power control mechanism is conventionally based on the SIR. The aim is to have all users follow a predefined SIR value as closely as possible [5]. In an ideal environment, signals from all users would arrive at the Base Station (BS) at equal power level. Thus, signals from a Mobile station (MS) closer to the BS would not overpower weaker signal coming from a distant MS. Signals from different MS are affected by different propagation loss from the wireless channel and the signal may suddenly drop drastically, leading to severe interference from other users and lower SIR. In order to compensate for the interference and increase the SIR, transmit power will have to be increased. If the compensation is not done properly and the power is increased too much, it will interfere with other MS and lowers their SIR. These MS will in turn compensate for this, by increasing their transmit power. If all MS increase their power for keeping their SIR at predefined level, it may lead to power escalation or positive feedback which could make the whole system to become unstable [5].

The scope of this work is limited to power control mechanism in the uplink direction only. Although, power control is also needed in the downlink direction, it is for another purpose, and it uses Signal - to - Noise - Ratio (SNR) for the transmit power control (TPC) command unlike in the uplink direction which makes use of Signal to Interference Ratio (SIR) for the same purpose.

II. Review of the State of the Art

[6] examined the estimation of SIR, the channel prediction techniques and the use of diversity antenna array in a power-controlled CDMA system. A new SIR estimator for CDMA systems in the uplink direction, using an auxiliary spreading

sequence method was proposed. [7] evaluated the power control mechanism of CDMA system and observed that feedback delay is one of the major problems that degrade the performance of power control algorithms in CDMA systems. To mitigate the effects of the feedback delay, an improved channel prediction algorithm based on Rayleigh fading conditions was developed. The proposed prediction algorithm, based on Least Mean Square method, leads to a considerable increase in the capacity of CDMA system, about 40% for fixed step algorithm and about 50% for variable step algorithm. [1] investigated the performance of the current power control mechanism and found out it did not have the capability to accommodate the quick variation of fast fading channels. To combat the variations of received SIR when the radio channel experiences slow fading and also adapt to rapid fading channels, a new algorithm that requires only one bit as specified in 3GPP specifications was designed. The proposed algorithm is superior in performance in static channels and also performs better in fast fading, than the fixed step size. [8] proposed a power control algorithm based on the modification of the transmitted power update step size. The algorithm dynamically modifies the step size to ensure more adapted power variations. [5] studied the conventional power control mechanism in CDMA and observed that a significant problem within the conventional methods is the slow SIR recovery from deep channel fades. This is because the conventional methods, based on the Power Control Command (PCC), on the current channel state which might have changed from the previous state, could lead to drastic change in SIR which, in turn, can cause power escalation and make the system unstable. To overcome power escalation and improve recovery from deep fades, a novel power control mechanism which predicts the next channel state was developed using Kalman filtering and Linear Quadratic Gaussian control. [9] designed an adaptive algorithm that utilized ideas from self-tuning control systems, to deal with random changes of radio channel and interference in CDMA systems, by limiting or controlling the feedback bandwidth.

As shown from the works reviewed, more effort has been expended on improving the power control mechanisms of CDMA systems. Several methods or algorithms have been proposed by each of the authors with their limitation(s) as earlier highlighted. This work is based on the work of [5] which proposed a new method of optimizing power control in CDMA system by predicting the next channel state that will be used for transmission. The same concept will be applied in this work, but for WCDMA system.

III. METHODOLOGY

This section is divided into three. The first part briefly describes the general concept of power control in WCDMA while the second describes the conventional closed loop power control mechanisms and the third the channel prediction approach.

(a) Power Control in WCDMA

Power control in 3G cellular mobile communications is categorized as open loop and closed loop. In open loop, the transmitting entity (MS or BS) measures the interference level in the channel and adjusts its transmission power accordingly [10]. By contrast, in the closed loop power control, one entity in the BS-MS connection does the measurement, and then feeds the result to the other entity which, in turn, adjusts its transmission power based on the information received. The closed loop is further sub-divided into inner loop (otherwise called the fast closed loop power control) and outer loop. The inner loop power control technique is used to adjust the transmission power based on the measured SIR at the other end of the connection. In the uplink, it is the MS that adjusts its transmission power based on the SIR measured by the BS. The outer loop simply functions to set the desired or target SIR for the system. Different channel parameters require different SIR values, the outer loop power control sets and adjusts this to obtain a high signal quality.

(b) Conventional Closed loop Power Control Mechanisms

In uplink closed loop power control, the control instruction and power control command (PCC) are fed through the downlink to the MS and is used to control the transmitting power. This is achieved by comparing the SIR target value to the currently received SIR. The generated error signal is then used to decide what instruction (PCC) needs to be fed back to the MS. The quantity by which the power is changed is usually called a step and may consist of one or several steps. The step size could be fixed, quantised or ideal.

(i) **Fixed Step size Method**

The fixed step size uses a single PCC-bit to adjust the MS power according to equation (1):

$$PCC - bit_k = sgn[SIR_k - SIR_T] = \begin{cases} -1, & SIR_k < SIR_T \\ +1, & SIR_k \geq SIR_T \end{cases} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. (1)$$

SIR_T is the target SIR while SIR_k is the measured SIR for user k.

By feeding back -1, the MS increases its power level by one step and by feeding back +1, the signal power decreases by one step. The advantage of having a fixed step size is the fact that the minimal bandwidth utilization for the PCC and the errors are less significant. The draw-back of this method however is that, using a single step size makes this method rather slow and especially noticeable during recovery from deep fades, where the step size should be increased.

(ii) **Quantized Step size Method**

This is a variable step algorithm where the number of steps is limited by the number of transmitted PCC-bits. The transmit power for the next slot $p_k(t+1)$ for user *k* is given as:

$$p_k(t+1) = p_k(t) + \mu_{Qk}(t) \ldots \ldots \quad (2)$$

where the quantized step size $\mu_{Qk}(t)$ given by:

$$\mu_{Qk}(t) = min[p_{kideal}(t) - p_k(t) + \mu_{stepsize}(t)] \ldots \ldots \quad (3)$$

$$p_{kideal}(t) = \frac{\sum_{j \neq k} p_j(t)}{\Gamma_k(t)} SIR_T \ldots \ldots \quad (4)$$

Where $\Gamma_k(t)$ is the measured channel gain for user k and

$$\mu_{stepsize} = \begin{cases} -2dB & min\,[p_{kideal}(t) - p_k(t) - 2] \\ -1dB & min\,[p_{kideal}(t) - p_k(t) - 1] \\ +1dB & min\,[p_{kideal}(t) - p_k(t) + 1] \\ +2dB & min\,[p_{kideal}(t) - p_k(t) + 2] \end{cases} \ldots \ldots \quad (5)$$

In an efficient power control system, this would be the most ideal method. However, because the PCC-bits are transmitted without coding, they are subjected to error. In fact, the longer the PCC-bits, the higher the risk of error. A major disadvantage is the increased bandwidth requirement when increasing the number of PCC-bits.

(iii) **Ideal Step size Method**

The ideal step size is usually used in simulations where an infinite number of PCC-bits is assumed. This method is useful when trying to find the best possible realizable power control scheme. The idea is to use the target SIR and find the ideal power which achieves this SIR (assuming the channel is known). The transmit power $p_k(t+1)$ for user *k* is given as

$$p_k(t+1) = p_k(t) + \mu_{Qk}(t) \ldots \ldots \quad (6)$$

where,

$$\mu_{kideal}(t) = p_{kideal}(t) - p_k(t) \ldots \ldots \quad (7)$$

(c) Channel Prediction Based Power Control Method

The proposed method employs Linear Quadratic Gaussian control and Kalman filtering to estimate the next channel state as suggested by [5].

It is assumed that the channel state is unknown and should be estimated. The received power P^* from each user is given by:

$$P^* = \frac{\beta\sigma^2}{1-\frac{\beta}{N}(K-1)} \ldots \ldots \quad (8)$$

where *K* is the number of users, *N* is the spreading gain, β represents the predefined SIR value that should be followed and σ^2 is the thermal noise variance.

To achieve the power control objective, a control command *u(t)* will be created. This is done in two stages:

First, controlling the received power *P(t)* requires that equation (9) is satisfied:

$$P(t+1) = P(t) + \mu(t) \ldots \ldots \quad (9)$$

The control command for the system should be designed in order to minimize the quadratic performance index given as:

$\sum_{t=0}^{\infty}[\| P(t) - P^* \|^2 + r_c \| \mu(t) \|^2]$
where r_c represents the design weight and it is used to tune the minimization. The optimal control law is given by:

$$\mu(t) = -\propto [P(t) - P^*] \quad (10)$$

where $$\propto = \frac{1+\sqrt{1+4r_c}}{2r_c+1+\sqrt{1+4r_c}}$$

Secondly, power control at the transmitter end requires the power to be updated according to equation (11):

$$p(t+1) = p(t) + \mu(t) \quad (11)$$

where $p(t)$ represents the transmitting power and $\mu(t)$ is given in equation (10).

Also,

$$P(t) = p(t) + \Gamma(t) \quad (12)$$

The control law can then be expressed as:

$$\mu(t) = -\propto [p(t) + \Gamma(t) - P^*] \quad (13)$$

where $\Gamma(t)$ represents the unknown channel that should be predicted.

p(t) given in (11) is used to predict the channel $\Gamma(t)$. By substituting the control law given by (13) into *p(t),* and using recursion, we have:

$$p(t) = (1-\propto)^L p(t-L) - \propto [(1-\propto)^0 \ldots\ldots (1-\propto)^{L-1}] \begin{bmatrix} \Gamma(t-1) \\ \vdots \\ \cdot \\ \cdot \\ \Gamma(t-L) \end{bmatrix} + P^* \quad (14)$$

$(1-\propto)^L p(t-L) \to 0$ when L is sufficiently large and $0 < \alpha \leq 1$.

Using Auto Regression, Γ can be modelled as:

$$\Gamma(t) = -h_1\Gamma(t-1) - h_2\Gamma(t-2) \ldots - h_L\Gamma(t-L) + e(t) \quad (15)$$

where h_j is assumed to be known and $e(t)$ is white noise.

For the observation process, the following equation is used:

$$\omega_k(t) = P_k(t) + \frac{1}{N}\sum_{j\neq k} P_j(t) + \sigma^2 + v_k(t) \quad (16)$$

$P_k(t)$ represents the received power for user *k* after despreading. σ^2 is the noise variance while $v_k(t)$ is the additional noise quantity which occurs as a result of an imperfect or non-ideal environment. As shown above, $Pk(t)$ tends to *P*.

The standard form for predicting the channel state is:

$$\Gamma_{t|t} = \Gamma_{t|t-1} + M[y_t - C\Gamma_{t|t-1}] \quad (17)$$

where $C = [1-\propto \; -\propto(1-\propto) \ldots\ldots -\propto(1-\propto)^{L-1}]$,
$y_t = w(t) - P - \lambda^2$ (measurable); *M* is derived from the Riccati Equation and $\lambda^2 = 10log_{10}\left(1 + \frac{1}{\beta}\right)$

The estimation model for the $\Gamma_{t|t}$ is employed to predict the next channel state $\Gamma_{t+1|t}$ with the standard form for prediction:

$$\Gamma_{t+1|t} = A\Gamma_{t|t} \quad (18)$$

where:

$$A = \begin{bmatrix} -h_1 & -h_2 & \dots & -h_L \\ 1 & 0 & \dots & 0 \\ & \ddots & & \vdots \\ & & 1 & 0 \end{bmatrix}$$

Having predicted the next channel state $\Gamma_{t|t-1}$, the resulting control law can be specified by:

$$u_{prediction}(t) = -\alpha\left[p(t) + \hat{\Gamma}_{t|t} - 1 - P^*\right] \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \quad (19)$$

IV. SIMULATION RESULTS AND ANALYSIS

Matlab simulations were done to demonstrate how the power control mechanisms (both the conventional methods and channel prediction method) work in a cellular network.

The following parameters are defined as variables in the MATLAB program and their values set as indicated below:

- Number of users (*K*)=8
- Message length (*n*)=4000
- Spreading code gain (*M*)=256
- Channel speed in km/h (*v*)=10Km/h
- Slot size (*k*)=40
- Target SIR in dB (β)=10dB
- Noise variance (σ^2)=0.02

By varying some of these parameters, the simulation can be implemented under different conditions.
The following system requirements are assumed for the simulation

- Message bits (of length *n* from K users)
- Channel (Rayleigh fading channel)
- Noise (Gaussian white noise of zero mean)
- Coding (codes of gain *M* with low cross correlation)
- Signal power updating schemes
  - ✓ Fixed SIR based using 1 level (1dB)
  - ✓ Quantized SIR based using 2 levels (1dB and 2dB)
  - ✓ Ideal SIR based
  - ✓ Channel prediction using Linear Quadratic Gaussian (LQG) and Kalman Filtering

The results of the simulation are displayed in a number of plots, each of which is made up of six graphs. For the purpose of simplicity, the same channel speed is used for all users.. The channel prediction method is then compared with the three conventional methods. Each plot shows 6 graphs in a 3 x 2 (row by column) arrangements. The graphs in the first row represent the Actual channel and the Predicted channel. The second row shows the Transmit Power for the current channel and the Predicted channel. On the third row is the SIR for the current conventional traditional and the SIR for the Predictive method.
The dotted line on the third row represents the target SIR of 10dB (β=10). The y-axis shows the Gain (dB) or the Power (dB) while the x-axis represents the slot number (total number of slots transmitted is 100 i.e ***n/k***). The focus of the analysis is on how the SIR in the third row follows the target SIR and how fast it can recover from deep fades in the channel. The mean and percentage of improvement of the predicted SIR is shown in Table 1, 2, and 3.

(i) **Fixed Step Size VS Proposed Method**

The graph below shows the performance of a fixed step size of 1dB against the New Method which predicts the channel.

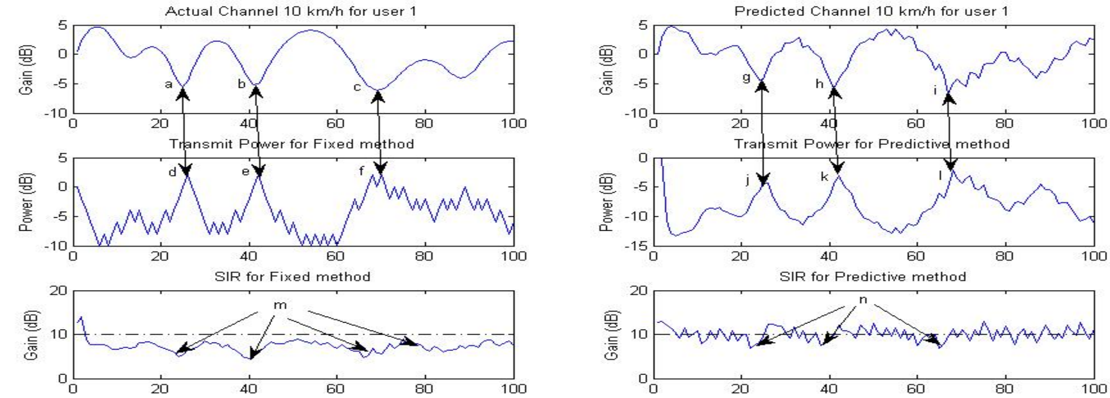

Figure 1: Fixed Step Size vs Proposed Method for user 1

In the figure 1 above, for user 1, there is a resemblance between the actual channel and the predicted channel. At points ‘a’ ‘b’ and ‘c’ in the Actual channel, there is slight fade. To compensate for this, the transmit power increases at points ‘d’ ‘e’ and ‘f’. Also, at points ‘g’, ‘h’ and ‘i’ on the predicted channel, there is slight fade as well while the transmit power increases at ‘j’, ‘k’ and ‘l’ to compensate for this. The predicted channel gain has a higher mean value of -0.11dB compared to that of the Actual channel of -0.46dB. The higher mean value of the predicted channel gain indicates a better performance with 75.64%. **(See Table 1).**

Note that at points ‘d’, ‘e’ ‘f’ and ‘j’, ‘k’, ‘l’, the transmit power is inversely proportional to the actual channel gain. The transmit power for the Predicted method is -8.29dB compared to that of Fixed method with -4.48dB. **(See Table 1).** This shows an improvement of 85.11% and indicates that the Predicted method achieves the least SIR to maintain connection with a lower power than the Fixed method.

At points ‘m’, the SIR is disturbed by deep fade. The Predictive method for SIR recovers faster than the Fixed Step method at point ‘n’ and has a more stable performance. The mean SIR for the Predictive method is 10.12dB which is very close to the target SIR of 10dB, unlike the mean SIR for the Fixed method which is 7.33dB. This confirms that the SIR for the Predictive method performs better than the Fixed method by 38.01%.**(See Table 1)**

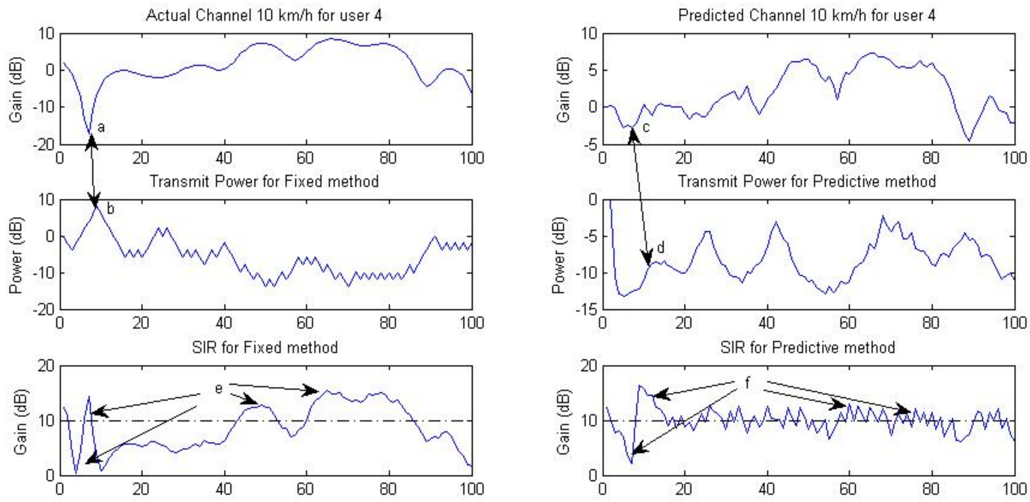

Figure 2: Fixed Step Size vs Proposed Method for user 4

For user 4 in figure 2, the Actual channel is a bit stable except for the deep fade at point ‘a’. The deep fade experienced at point ‘c’ in the Predicted channel is not as severe as that of point ‘a’ in the Actual channel. The mean value of the Predicted channel gain is 2.02dB as against the Actual channel gain of 1.62dB. The Predicted channel gain is higher than the Actual channel gain with an improvement of 24.91%. **(See Table 1)**

The Transmit power increases at points ‘b’ and‘d’ to mitigate the effects of the deep fade experienced at points ‘a’ and ‘c’. The Transmit power for the Predicted channel is lower than that of the Actual channel (-8.29 dB against -5.80 dB) respectively. This is an improvement of 42.98%. **(See Table 1)**

The SIR for the Fixed Step method experiences deviation from the target SIR at point “e’. The SIR for Predictive method recovers faster from deep fade and settles closely to the target SIR at point ‘f’ .The Predicted SIR has a mean value of 9.95dB which is closer to the target SIR of 10 dB than the mean value of the SIR for Fixed method which is 8.66 dB. This is an improvement of 14.89%. **(See Table 1)**

(ii) Quantised Step Size VS Proposed Method

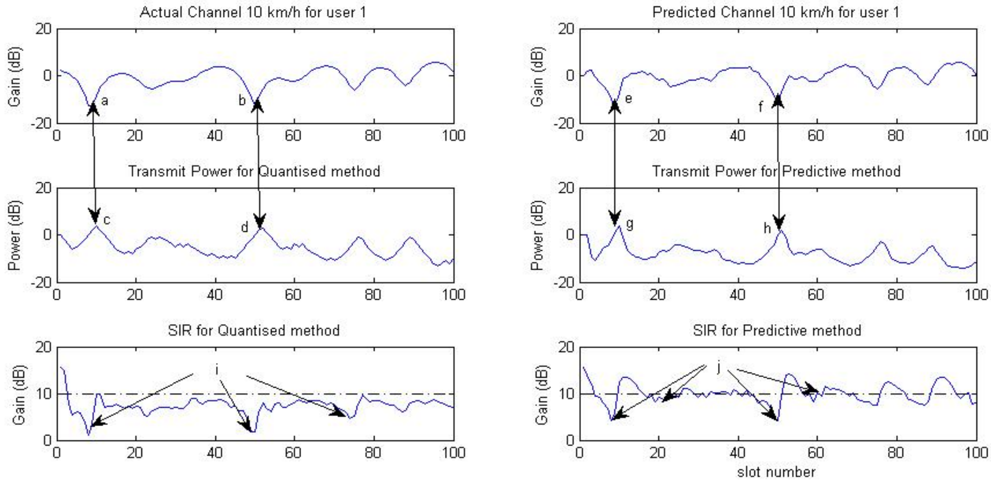

Figure 3: Quantised Step Size vs Proposed Method for user 1

In figure 3, the actual channel experiences shallow fade at points ‘a’ and ‘b’ while the transmit power in increased at point ‘c’ and ‘d’ to compensate for it. The predicted channel closely resembles the actual channel at points ‘e’ and ‘f’ but with a mean value of -0.27dB as against -0.78dB for the Actual channel. This translates to an improvement of 65.02% over the Actual channel. **(See Table 2)**

Likewise, the predicted method transmits with a lower Tx power (-8.15dB) as compared to Quantised method with a mean Tx power of -5.5dB. This shows that the Predicted method performs more efficiently than the Quantised method by 48.22%. **(See Table 2)**

The SIR for the Predicted method recovers faster, performs better and settles closely to the target SIR of 10dB at point ‘j’ than the Quantised method at point ‘i’. The Predictive SIR has a mean value of 9.98dB which is closer to the target SIR of 10dB than the Quantized method with a mean value of 7.32dB. This indicates an improvement of 36.21%. **(See Table 2)**

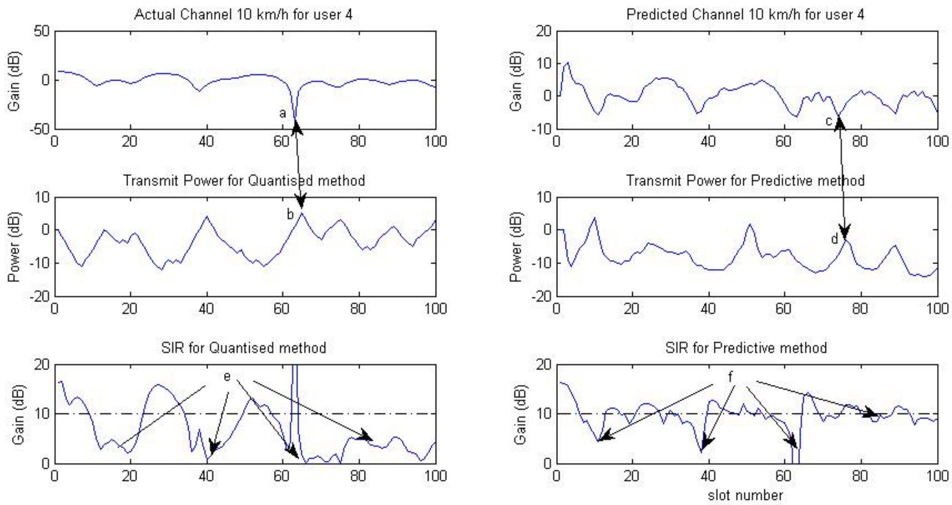

Figure 4: Quantized Step Size vs Proposed Method for user 4

For user 4, the Actual channel is relatively stable but for the deep fade at point ‘a’. This increases in the Transmit power at point ‘b’ make up for this deep fades at point ‘a’. The Predicted channel suffers less deep fade at point ‘c’. It has improvement of 46.90% over the Actual channel. **(See Table 2)**
The SIR for Quantized method for user 4 experiences higher deviations from the target SIR of 10dB as shown at point ‘e’ in row 3. On the contrary, the SIR for the Predicted method stays closer to the target SIR with a mean value of 9.86dB as against the Quantized method. Also, the Predicted method recovers from deep fade quickly at point ‘f’ than the Quantized method at point ‘e’. This gives an improvement of 54.55% over the SIR for the Quantized method. **(See Table 2)**

(iii) **Ideal Method VS Proposed Method**
Here, the Predictive method is compared with the Ideal method. Note that the Ideal makes use of infinite number of bits for the power control command (PCC) which is not realistic.

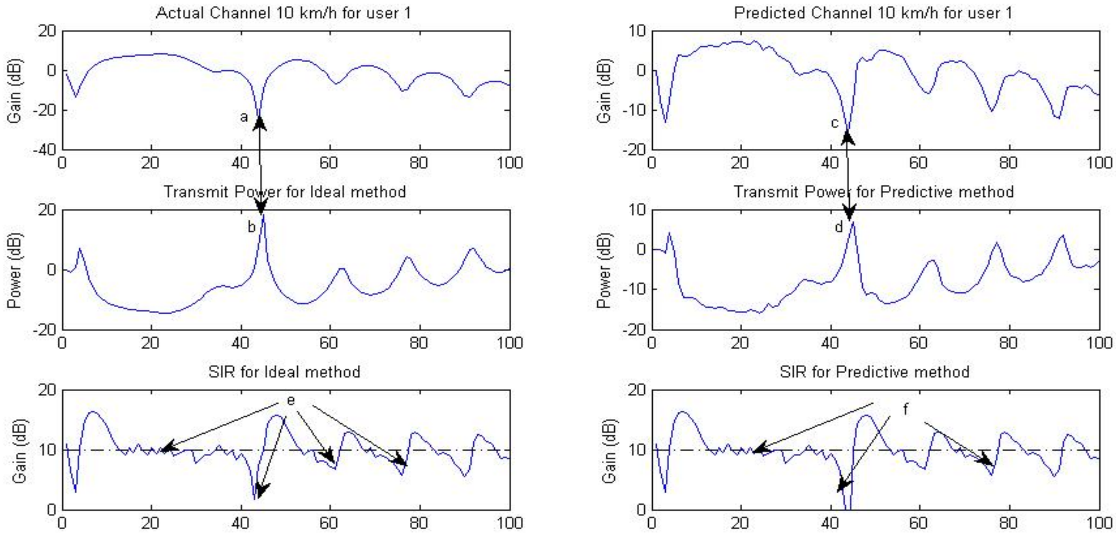

Figure 5: Ideal Method vs Proposed Method for user 1

For user 1 in the Ideal method, the Actual channel suffers deep fade at point ‘a’ and the Transmit power increases at point ‘b’ to make up for it. The Predicted channel experiences less fade at point ‘c’ which gives an improvement of 54.64%. **(See Table 3)**
The SIR for both the Ideal method and the Predicted method are relatively stable. They both recover faster from deep fade and settles well to the target SIR **(See Table 3)**

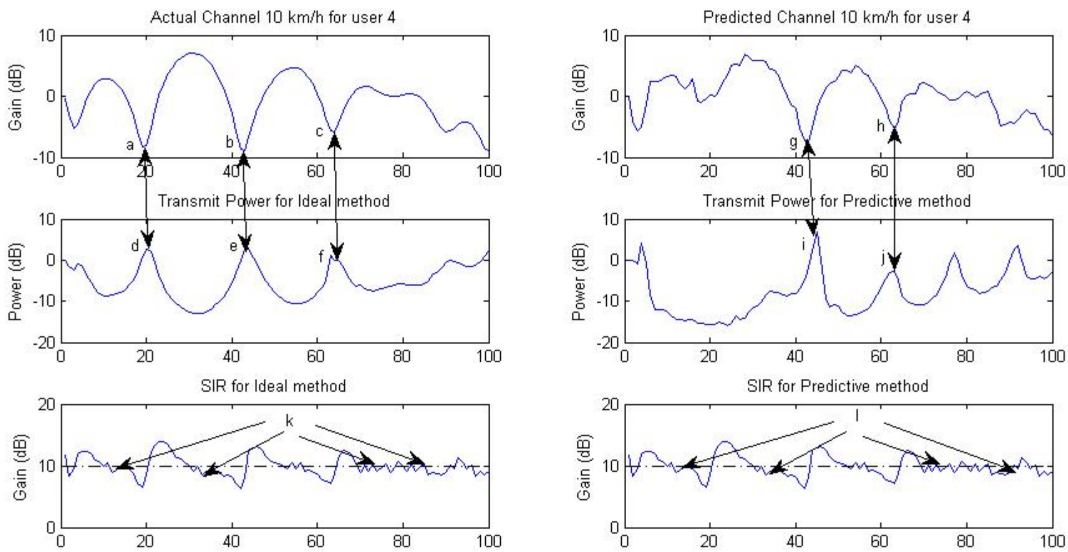

Figure 6: Ideal Method vs Proposed Method for user 4

For user 4 in the Ideal method, the Actual channel experiences at points ‘a’, ‘b’ and ‘c’. To mitigate the effects of this deep fade, the Transmit power increases at points‘d’, ‘e’ and ‘f’. Likewise the Predicted channel and the Transmit power at points ‘g’, ‘h’ and points ‘i’, ‘j’ respectively.
At points ‘k’ and ‘l’, the SIR for the Ideal and the Predictive methods also settle closely to the predefined SIR target of 10dB and they both have steady performance.

Table 1: Comparison of Mean Values and Percentage Improvement of Fixed Method and Proposed Method

SLOT NO	CHANNEL GAIN (MEAN VALUE)			TX POWER (MEAN VALUE)			SIR (MEAN VALUE)		
	Actual	**Predicted**	**%**	**Actual**	**Predicted**	**%**	**Actual**	**Predicted**	**%**
USER 1	-0.463	-0.113	75.640	-4.480	-8.293	85.114	7.334	10.122	38.013
USER 2	-2.659	-0.777	70.787	-3.840	-8.293	115.966	8.592	10.064	17.131
USER 3	-2.571	-1.051	-59.130	-3.200	-8.181	155.670	6.252	10.099	61.516
USER 4	1.622	2.026	24.919	-5.800	-8.293	42.985	8.666	9.956	14.895
USER 5	0.820	1.066	29.964	-6.240	-8.293	32.902	8.616	10.000	16.061
USER 6	2.333	2.506	7.400	-6.100	-8.293	35.953	9.047	10.320	14.067
USER 7	-5.097	-2.504	50.871	0.160	-8.293	5283.190	4.387	9.876	125.140
USER 8	0.839	1.093	30.304	-6.040	-8.293	37.303	8.717	9.993	14.631

Table 2: Comparison of Mean Values and Percentage Improvement of Quantised Method and Proposed Method

SLOT NO	CHANNEL GAIN (MEAN VALUE)			TX POWER (MEAN VALUE)			SIR (MEAN VALUE)		
	Actual	**Predicted**	**%**	**Actual**	**Predicted**	**%**	**Actual**	**Predicted**	**%**
USER 1	-0.794	-0.278	65.023	-5.500	-8.152	48.223	7.328	9.982	36.217
USER 2	0.168	0.736	339.264	-5.657	-8.235	45.576	8.124	9.950	22.476
USER 3	1.702	2.230	31.015	-6.350	-8.152	28.382	9.683	10.045	3.738
USER 4	-1.173	0.287	124.485	-3.750	-8.152	117.394	6.384	9.867	54.559
USER 5	3.622	3.265	-9.866	-8.800	-8.152	-7.361	10.951	10.072	-8.029
USER 6	0.573	1.116	94.976	-6.870	-8.152	18.665	9.448	9.721	2.885
USER 7	1.439	1.808	25.637	-5.760	-8.152	41.532	8.665	10.005	15.471
USER 8	-1.237	0.236	119.099	-4.450	-8.152	83.197	7.707	9.607	24.646

Table 3: Comparison of Mean Values and Percentage Improvement of Ideal Method and Proposed Method

SLOT NO	CHANNEL GAIN (MEAN VALUE)			TX POWER (MEAN VALUE)			SIR (MEAN VALUE)		
	Actual	**Predicted**	**%**	**Actual**	**Predicted**	**%**	**Actual**	**Predicted**	**%**
USER 1	-1.061	-0.481	54.643	-5.379	-8.021	49.110	10.030	10.030	0.000
USER 2	1.518	1.686	11.042	-8.235	-8.021	-2.592	10.236	10.129	-1.047
USER 3	2.006	2.167	8.023	-8.544	-8.021	-6.114	10.018	10.018	0.000
USER 4	-0.478	0.299	162.680	-5.372	-8.021	49.313	9.947	9.947	0.000
USER 5	3.149	3.273	3.964	-9.635	-8.021	-16.753	10.068	10.287	2.180
USER 6	1.495	1.857	24.200	-7.828	-8.021	2.463	10.293	10.336	0.427
USER 7	0.466	1.092	134.388	-6.629	-8.021	20.994	10.164	10.164	0.000
USER 8	2.284	2.587	13.251	-8.235	-8.021	-2.597	10.098	10.098	0.000

As can be seen from Tables 1, 2 and 3, the channel prediction method outperforms the conventional methods in all the parameters of interest namely, the channel gain, transmitted power and the SIR. Except for some very few cases like user 5 under the quantized method. Also we could observe that the ideal method has lower transmitted power for user 2, 3, 5 and 8. This should not be a concern, since the ideal situation is not realistic. The same argument applies to the better SIR value (i.e closer to the target SIR) in the ideal case.

In practice, to fully utilize the capacity and improve the performance of WCDMA systems, the signal to interference ratio (SIR) must strictly follow a predefined target SIR which is the same for all users. This is achieved by designing a power control mechanism that ensures all mobile stations signals get to the base station at equal strength. One major impediment to achieving this objective is the slow recovery from deep fades which occurs as result of small scale propagation loss in the channel. This deep fade causes a significant drop in the SIR. If the SIR does not recover properly, the mobile station continues to increase its transmit power after every drop in SIR. This leads to destructive multiple access interference (MAI) i.e blocking out weaker signals. Also, other mobile stations will increase their transmit power to compensate for the drop in their SIR. This causes power escalation as a result of positive feedback. These two effects (destructive MAI and power escalation) lead to poor reception quality and can make the WCDMA system go unstable.
From the results of the simulations, it is very obvious that the proposed Predictive power control mechanism enhances the channel recovery from deep fades in comparison to the conventional power control. Consequently, the results presented in tables 1 2 and 3, show a steady SIR performance for the Predictive method. For most of the cases investigated, the mean value of the predicted SIR is always closer to the target SIR of 10dB. This signifies that the proposed method is better than the conventional

methods. Furthermore, the better channel gain and lower transmit power of the proposed method implies lower power requirement and better efficiency/performance of the communication system. This also indicates lower interference, enhanced reception quality, more steady system and lower power consumption, hence longer battery life of mobile stations.

V. Conclusion

A channel prediction based power control mechanism was implemented for the WCDMA network. Most importantly, the SIR obtained from the new method is very close, many a times approximately equal to the target SIR while the conventional methods indicated some divergence from the target SIR. Similarly the transmit power under the channel prediction model was considerable lower than the conventional methods while the channel gain is considerably higher. In fact, it is noteworthy that the new method even outperforms the Ideal step size method, which is a theoretical method not generally adopted in a real environment. The results show that the predictive algorithm predicted the channels with reasonable level of accuracy. There is considerable similarity between the actual channel and the predicted chain.

References

[1] R. Patachaianand , K Sandrasegaran, 2006, *"A New Adaptive Power Control Algorithm for UMTS"*. University of Technology Sydney: Institute of Information and Communication Technologies and Faculty of Engineering.

[2] H. Bakhsi, S. Khodadadi, 2009, *"A New Power Control Algorithm for Cellular CDMA Systems"*. Journal of Information and Computing Science, vol.4, no.3, pp. 205-210.

[3] J. Yu, S. B. Wu, J. Z. He, 2006, *"A Novel Method of SIR Measurement for Power Control in CDMA Systems"*. Journal of Physics: Conference Series *48*, pp.457-461. [Online]. Available at iopscience.com (Accessed July 1, 2014).

[4] J. Florido, 2005, *Power Control for WCDMA*, PhD Dissertation. Spain: The University Polytechnic, Catalunya.

[5] T. Uurtonen, 2005, *Optimized Power Control for CDMA using Channel Prediction*. Norrkoping, Sweden: Department of Science and Technology, Linkopings University.

[6] A. Kurniawan, 2003, *Predictive Power Control in CDMA Systems*, PhD Dissertation. The University of South Australia: Institute for Telecommunication Research.

[7] A. Kurniawan, I. Iskander, S. Machdar, 2009, *"Improved Predictive Power Control Algorithms to Increase CDMA System Capacity"*. ITB J. Eng. Sci. Vol. 41, No. 2, pp.187-200.

[8] L. Nuaymi, X. Lagrange, P. Godlewski, 2002, "A Power Control Algorithm for 3G WCDMA System". *European Wireless, France*.

[9] M. Rintamaki, 2005, Adaptive Power Control in CDMA Cellular Communication System. Dissertation for Doctor of Science Degree in Technology. Helsinki University of Technology: Department of Electrical and Communication Engineering.

[10] J. Korhonen, 2003, "Introduction to 3G Mobile Communication", second edition, *Artech House Mobile Communications Series*.

[11] K. Qaraqe, W. Al-Fudhaili, 2003, "SIR Estimation for Closed-Loop Power Control in WCDMA System". Saudi Telecom Company: Future Mobile Technologies, Research and Development Group.

[12] A. Al-Mamun S. Islam, F. Yesmin, M. Akter, S. A. Jahan, 2009, "Novel Adaptive Step Power control Algorithm for 3G WCDMA Cellular System". *Proceedings of 2009 12th International Conference on Computer and Information Technology (ICCIT 2009)* pp. 526-530.

[13] A. AbdulRahim, 2008, WCDMA Simulation for Transmitter Part and BER Performance in AWGN, Rayleigh Channel and Rician. Bachelor of Engineering Thesis. University Teknikal: Faculty of Electronic and Computer Engineering.

[14] P. Hende, S. Rangan, M. Chiang, X. Wu, 2008, "Distributed Uplink Power Control for Optimal SIR Assignment in Cellular Data Networks". *Networking, IEEE/ACM Transactions on* Networking, Vol.16, Issue. 6 pp.1420-1433.

[15] A. Gachhadar. 2012, "Modified Variable Step Size Power Control Algorithm for CDMA Systems". *International Journal of Scientific & Engineering Research*, vol. 3, no.10, pp. 1-5.

[16] S. Ulukus, R. Yates. 1998, "Stochastic Power Control for Cellular Radio Systems". IEEE *Transactions on Communications*, vol.46, no. 6, pp. 1-31.

[17] V. Vemasani, B. Appuni, 2005, "Performance Evaluation of Power Control Algorithm in Cellular Radio Communication Systems", Master Thesis. Blekinge Institute of Technology, Karlskrona, Sweden: School of Engineering.

[18] B. H. Walke P. Seidenberg, M. P. Althoff, 2003, UMTS: The Fundamentals. England: John Wiley & Sons Ltd.

[19] H. Holma, A.Toskala, 2004, WCDMA FOR UMTS – Radio Access for Third Generation Mobile Communications, 3rd ed. England: John Wiley & Sons Ltd.

[20] H. Holma, A.Toskala, 2007, WCDMA FOR UMTS – HSPA EVOLUTION AND LTE, 4th ed. England: John Wiley & Sons Ltd.

[21] S. Gunaratne T. G. Jeans, R. Tafazolli, B. G. Evans, 2002, "Comparison of SIR Estimation Techniques for Closed-Loop Power Control In WCDMA System". University of Surrey, Guildford, Surrey GU2 7Xh, UK: Centre for Communication Systems Research.

[22] E. Falletti F. Vipiana, L. Lo Cigno, 2000, "On SIR & BER Approximations in DS-CDMA System". Torino Polytechnic, Department of Electronic.

[23] M. M. Rahman Md. K. Islam. Y. Hassan-Al-Mahmud, A. R. Mahmud, 2012, "Performance Analysis of Downlink Power Control in WCDMA System". *International Journal of Scientific & Engineering Research*, vol. 3, no.8, pp. 1-6.

[24] R. Patachaianand, K. Sandrasegaram, 2006, "Performance Comparison of Adaptive Power Control in UMTS". University of Technology, Sydney: Faculty of Engineering.

[25] S. Koskie, Z. Gajic, 2003, "SIR-based Power Control Algorithms for Wireless CDMA Networks: An overview", *Dynamics of Continuous Discrete and Impulsive Systems B: Applications and Algorithms*, vol. 10-S, pp. 286–293.

[26] S. Haykin, M, Moher, 2004, *Modern Wireless Communications*. London: Pearson Education.