Performance Comparison of Adaptive Power Control in UMTS for Indoor Propagation

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Abstract

Power control is a burning issue in modern wireless communication systems. Specially, in systems based on Code Division Multiple Access (CDMA) technology used in Universal Mobile Telecommunication System (UMTS), power control is adopted for maximizing the overall capacity of wireless system and battery life of mobiles terminals. A number of adaptive methods for power control in UMTS for different outdoor environments were reported in literature, but the focus on power control for indoor environments remained negligible. So this paper aims to perform a comparative analysis of above mentioned power control techniques for different indoor propagation models. Performance evaluation was carried out on the basis of overall spectral efficiency (SE) and power control error (PCE).

Keywords: *UMTS, Adaptive Power Control, Performance evaluation, Spectral efficiency, Power control error (PCE), Indoor Propagation Models*

1. Introduction

Universal Mobile Telecommunication System (UMTS) is based on Code Division Multiple Access (CDMA) technology. In CDMA based systems multiple users simultaneously communicate in a single frequency band. For any user, at the base-station received signal power from all other users is considered as interference. A user closer to the base-station transmitting at the same power as another at the cell edge, will block out the later. This problem of CDMA based system is usually named as near-far problem [1].

The near-far problem in any UMTS must be combat to maintain reliable links to all users as it can adversely affect the overall performance of the system [1]. For keeping the interference, caused due to this near-far problem, to a manageable level a proper power control method can be adopted. In literature, several power control methods have been proposed, which are based on path loss between the user and the base-station [2-5].

The basic purpose of each power control method is to equalize the received signal power from all users based on their distances from the base-station. Some of the methods perform power control when there is no dedicated link between user and base-station (i.e. Node B).

This type of power control methods are categorized as Open-loop power control. While some methods ensure power control for dedicated links based on Signal-to-Interference Ratio (SIR), and they fall in the category of Closed-loop power control.

Closed-loop power control can be further disintegrated into two main types: Outer-loop and Inner-loop power control. Based on the requirements, the former is responsible for setting the target Signal-to-Interference Ratio (SIR) while Inner-loop power control handles the transmission power to maintain the received SIR at Node B equal to the SIR target.

So far, power control methods have been proposed and evaluated only for outdoor propagation models [6] but they are not studied for indoor environments. As increased capacity and quality of service for indoor propagation models is the need of hour, so it will be interesting to observe effects of existing power control methods on different indoor propagation models.

This paper aims at comparing a number of existing adaptive power control methods under different indoor propagation models. For this purpose, following four adaptive power control methods have been evaluated: First method is Adaptive Step size Closed-Loop Power Control (AS-CLPC) proposed by Kim, et. al., [2]. This method adjusts the step size on the basis of a previous power control command. Second adaptive power control method adjusts the step size on basis of a set of previous power control commands, it was proposed in [3] and named as Blind Adaptive Closed-Loop Power Control (BA-CLPC). Whereas, third and fourth method, Speed Adapted Closed-Loop Power Control (SA-CLPC) [4] and Mobility Based Adaptive Closed-Loop Power Control (MA-CLPC) [5] respectively are based on knowledge of user speed. Performance of all of these methods have been evaluated for three different empirical indoor propagation models namely: One-Slope Model [7], Motley-Keenan Model [8] and the COST 231 Multi-Wall Model [9].

Rest of the paper is organized as follows. Section 2 describes a review of power control in UMTS. Section 3 reviews three empirical indoor propagation models. The experimental setup has been discussed in Section 4. Simulation results were discussed in Section 5. Finally, the paper is concluded in Section 6.

2. Power Control in UMTS

This section gives a brief account of four adaptive power control methods reported in literature [2-6], Adaptive Step size Closed-Loop Power Control (AS-CLPC) [2], Blind Adaptive Closed-Loop Power Control (BA-CLPC) [3], Speed Adapted Closed-Loop Power Control (SA-CLPC) [4] and Mobility Based Adaptive Closed-Loop Power Control (MA-CLPC) [5]. All of these methods fall into the class of Inner-loop Power Control, which is a subclass of Closed-loop power control as discussed in Section 1.

Inner-loop power control also called fast closed-loop power control in the uplink direction (user to Node B) is the ability of user to adjust its power according to one or more Transmit Power Control (TPC) commands, in order to keep the received Signal-to-Interference Ratio (SIR) at a given SIR target [6, 10].

The TPC command provides us with the information of increment/decrement in the step size of power control using (1) [6, 10].

$$TCP_i(t) = sign\left(SIR_{tr}^{i}(t) - SIR_i(t)\right) \qquad (1)$$

Where $sign$ is the signum function, SIR_i is the Signal-to Interference Ratio (SIR) of i^{th} user at time t and SIR_{tr}^{i} is the target SIR as given in [6]. The i^{th} user adapts its transmit power P_i on next time slot $(t+1)$ according to TPC command given in (1) by using (2) [6, 10].

$$P_i(t+1) = P_i(t) + \delta_i(t) \cdot TCP_i(t) \qquad (2)$$

Where $\delta_i(t)$ is a power control step size of i^{th} user at time t and obtained using following adaptive methods:

2.1. Adaptive Step Size Closed-Loop Power Control (AS-CLPC)

Adaptive Step Size Closed-loop Power Control (ASCLPC) proposed by Kim, et. al., [2] is based on a single-bit adaptive step size power control scheme. This algorithm adapts its step size in accordance with the power control (TPC) command history. The step size $\delta_i(t)$ for i^{th} user is given by (3) [2, 6].

$$\delta_i(t) = \begin{cases} \delta_i(t-1) \cdot K & , \ if\ TCP_i(t) = TCP_i(t-1) \\ \delta_i(t-1)/L & , \ otherwise \end{cases} \qquad (3)$$

Where K is a positive real constant with a range of $1 < K$ and L is a positive real constant with a range of $1 < L < 2$ as suggested by [6].

2.2. Blind Adaptive Closed-Loop Power Control (BA-CLPC)

Blind Adaptive Closed-Loop Power Control (BA-CLPC) method presented by Nourizadeh, et.al., [3] adapts power control step sizes according to user mobility. According to algorithm, step size is increased by 0.25 if previous two Transmit Power Control (TPC) commands are with same sign, otherwise it will be reset to 1dB.

2.3. Speed Adapted Closed-Loop Power Control (SA-CLPC)

Power control step size is adjusted in Speed Adapted Closed-loop Power Control (SA-CLPC) [4] on basis of user speed. In this algorithm each user is assigned with an optimal step size according to its speed. It is a table lookup process that means for a specific range of speeds an optimal step size is assigned. Although it seems that an accurate estimate of user speed is mandatory for this algorithm, but according to [4] it performs well in cases of rough speed estimations as well.

2.4. Mobility Based Adaptive Closed-Loop Power Control (MA-CLPC)

Mobility Based Adaptive Close-Loop Power Control (MA-CLPC) proposed by Lee at al. [5] is also based on the user speed. But the difference between MA-CLPC and SA-CLPC discussed previously is that MA-CLPC depends on the TPC command history as well. This algorithm requires three previous TPC commands and current user speed to adjust the step size. The step size $\delta_i(t)$ for i^{th} user as proposed in [5, 6] can be determined using (4).

$$\delta_i(t) = \delta_b \cdot f\left(R_0, R_1, R_2\right) \qquad (4)$$

Where δ_b is the basic step size determined by the user speed [5], R_0 is the current TPC command bit and R_1, R_2 are previous TPC command bits respectively.

3. Indoor Propagation Models

Above mentioned four adaptive power control methods are evaluated under three different indoor propagation models namely: One-Slope Model [7], Motley-Keenan Model [8] and the COST 231 Multi-Wall Model [9] are elaborated in next sub sections.

3.1. One-Slope Model

The empirical One-Slope Model is simplification of free space [7]. It maintains a linear dependence between the path loss (dB) and the logarithmic distance The One-Slope path loss model is expressed using (5).

$$L = L_0 + 10n \cdot \log(d) \qquad (5)$$

Where L_0 is the path loss at 1 meter distance, n is power decay index and d is the distance between base-station and the user. The One Slope Model is very fast, because it depends only on the distance d between transmitter and receiver.

3.2. Motley-Keenan Model

The Motley Keenan Model [8] considers all the walls intersecting the direct ray between base-station and user as an attenuation. Motley Keenan Model can be expressed using (6).

$$L = L_{OS} + L_0 + \sum_{i=1}^{l} L_{wi} \qquad (6)$$

Where L_{OS} is free space loss between base-station and user, L_0 is the path loss at 1 meter distance, L_{wi} is loss due to i^{th} wall, and l is the total number of walls.

3.3. COST 231 Multiwall Model

The COST 231 Model presented by [9] is the most sophisticated empirical model. In this model not only all walls intersecting the direct ray between base-station and user are considered but also the material properties of each wall are taken into account. The COST 231 Multi-wall Model can be given by (7).

$$L = L_{OS} + L_0 + \sum_{i=1}^{l} K_{wi} L_{wi} \qquad (7)$$

Where L_{OS} is free space loss between base-station and user, L_0 is the path loss at 1 meter distance, L_{wi} is loss due to i^{th} wall of type K_w, and l is the total number of walls.

4. Experimental Setup

In this section, the complete experimental setup created in MATLAB for simulating and analyzing the power control methods is explained with following steps:

1. The first step is to initialize the values for MATLAB simulator as given in the Table 1.

2. In second step, after placing the base-stations *(Tx)* on equal distances, users *(Rx)* are randomly activated and assigned to each *Tx* on basis of minimum distance from *Rx* to *Tx*. Figure 1 shows the placement of base stations and users of one time slot *t*.

3. Thirdly, target Signal-to-Interference Ratio SIR_{tr} is calculated for the time slot *t* by using (8).

$$SIR_{tr}(t) = 1/N \qquad (8)$$

   Where N is the number of users activated in time slot t.

4. In next step, we calculate Signal-to-Interference Ratio SIR_i for i^{th} user by using (9) [6].

$$SIR_i(t) = \frac{P_i(t)\cdot G_i(t)}{\sum_{i\neq j} P_j(t)\cdot G_{ij}(t) + P_N} \qquad (9)$$

   Where $P_i(t)$ is the transmit power of i^{th} *Rx* at time *t*, P_N is the noise variance, and G_i is the path gain of link between i^{th} *Rx* and its corresponding *Tx*. This path gain G_i is obtained by using the all three indoor propagation models discussed in Section 3.

5. Now SIR_i of each user *Rx* is compared with target Signal-to-Interference Ratio and Transmit Power Control (TPC) command for time *t* generated for each *Rx* by using (1).

6. Then on basis of TPC command, transmit power $\left(P_i(t+1)\right)$ of each user is adapted for the next time slot $(t+1)$ by applying the adaptive power control methods discussed in Section 2.

7. Finally, each user *Rx* is randomly allowed to move to new positions for next time slot $(t+1)$ with a speed $SP_i(t+1)$ using (10).

$$SP_i(t+1) = SP_i(t) \pm \varepsilon \qquad (10)$$

   Where $SP_i(t)$ is the speed of i^{th} Rx at time t and ε is the step size for speed increment/decrement. In simulations ε is chosen as $10m/\sec$.

Table 1. Initializing Values to Simulator

No:of Base-Stations (Tx)	4
No: of users (Rx)	100
No: of Iterations	10000
Power of Tx	24 dB
Power of Rx	10 dB
Rx assiging to Tx	Rand
Speed Steps	10 m/sec
Wall to Wall Distance	200 meters

After creating complete experimental setup in MATLAB, Power Control Error (PCE) is measured by running the simulator for a number of time slots. Details for SE and PCE are given in next section.

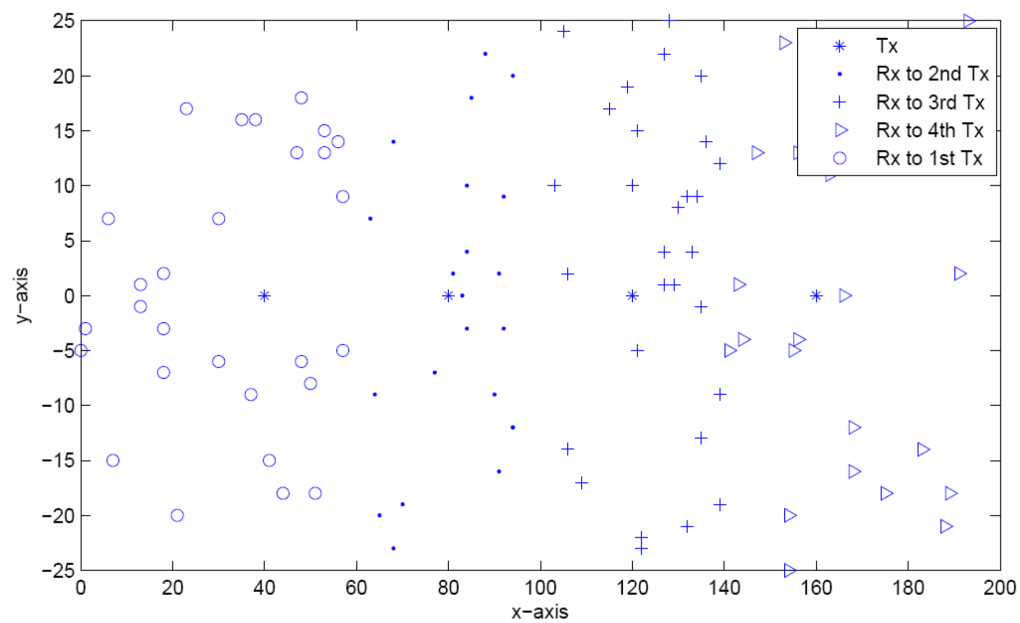

Figure 1. Placement of Base Station (Tx) and user Rx Assignment to each Tx on Basis of Minimum Distance

5. Results and Discussion

In this section, performance of four adaptive power control methods under three different indoor propagation models has been analyzed on basis of Power Control Error (PCE). Power Control Error can be defined as the expected value of differences between the target SIR (SIR_{tr}) and Signal-to-Interference Ratio (SIR_i) of i^{th} user for all time slots. Mathematically, it can be represented by (11):

$$PCE = E\left[\sqrt{\left(SIR_{tr}(t) - SIR_i(t)\right)^2}\right] \qquad (11)$$

For the analysis purpose, adaptive power control methods have been classified into two classes on basis of speed knowledge. First two methods AS-CLPC [2] and BA-CLPC [3] do not cater for speed during adapting power control step size, while SA-CLPC [4] and MA-CLPC [5] are methods which cater for speed as well.

Figure 2, Figure 3 and Figure 4 show the performance of AS-CLPC and BA-CLPC under three indoor propagation models (i.e. One-Slope Model [7], Motley-Keenan Model [8] and the COST 231 Multi-Wall Model [9]) respectively. By looking at these PCE plots, we can conclude that AS-CLPC outperforms the BA-CLPC.

For known speed, PCE plots for SA-CLPC and MA-CLPC under the respective indoor propagation models are given in Figure 5, Figure 6 and Figure 7, from which it is obvious that SA-CLPC has lesser PCE for all indoor propagation models.

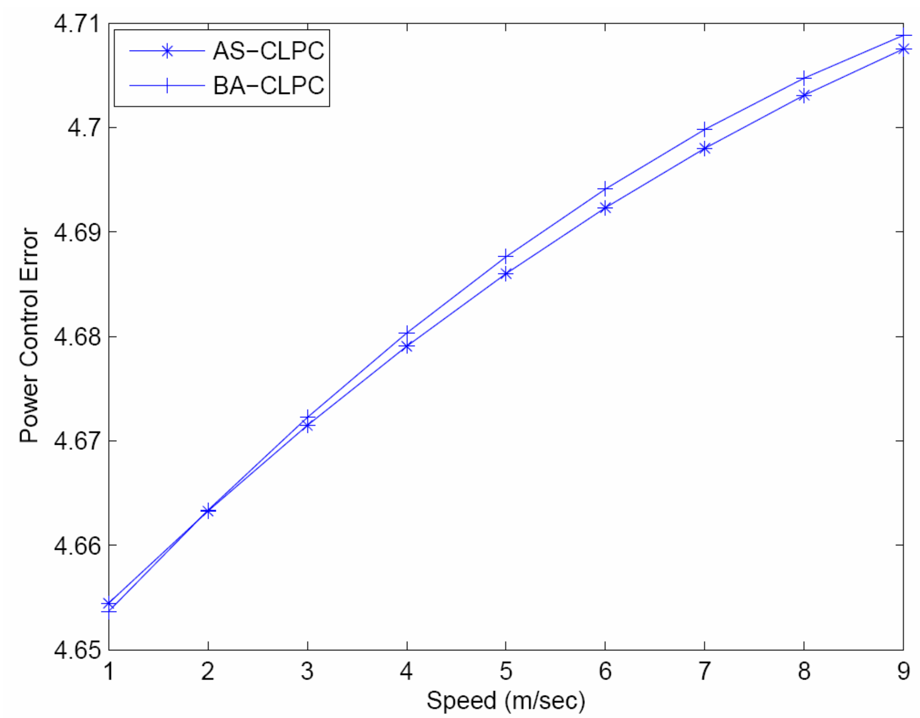

Figure 2. Power Control Error (PCE) of AS-CLPC and BA-CLPC under One-Slope Indoor Propagation Model

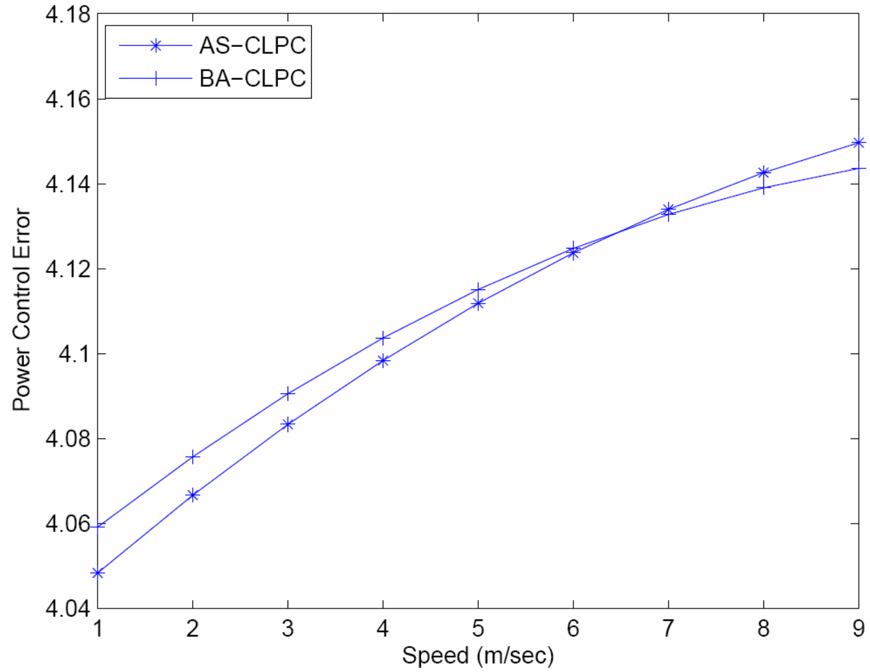

Figure 3. Power Control Error (PCE) of AS-CLPC and BA-CLPC under Motley-Keenan Indoor Propagation Model

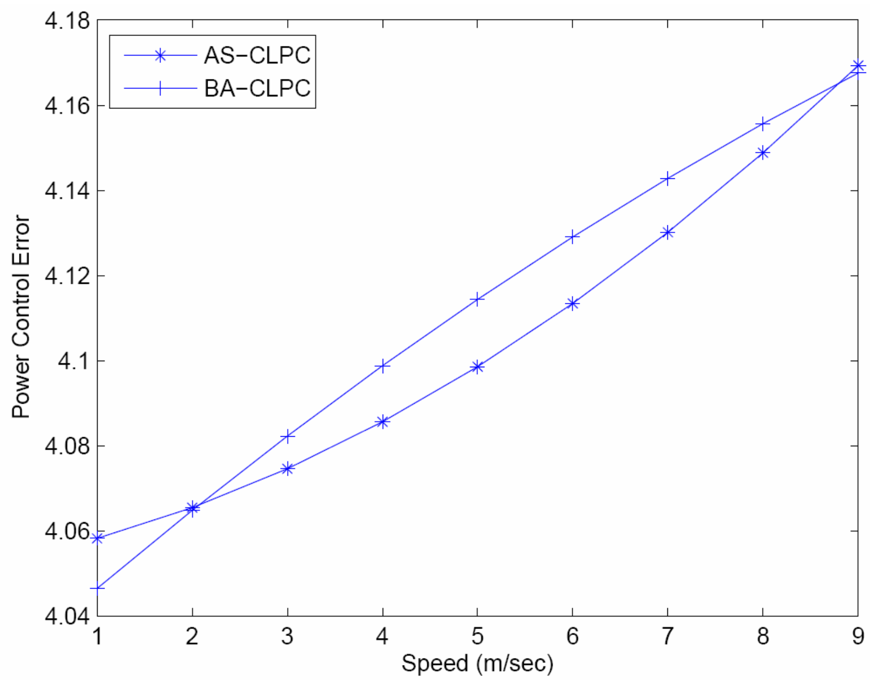

Figure 4. Power Control Error (PCE) of AS-CLPC and BA-CLPC under COST 231 Multiwall Indoor Propagation Model

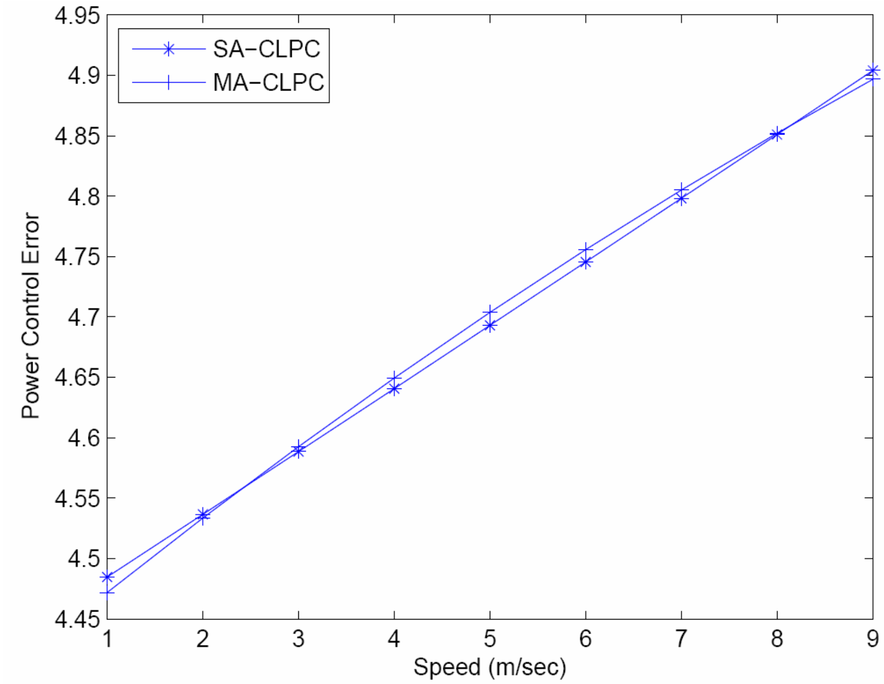

Figure 5. Power Control Error (PCE) of SA-CLPC and MA-CLPC under One-Slope Indoor Propagation Model

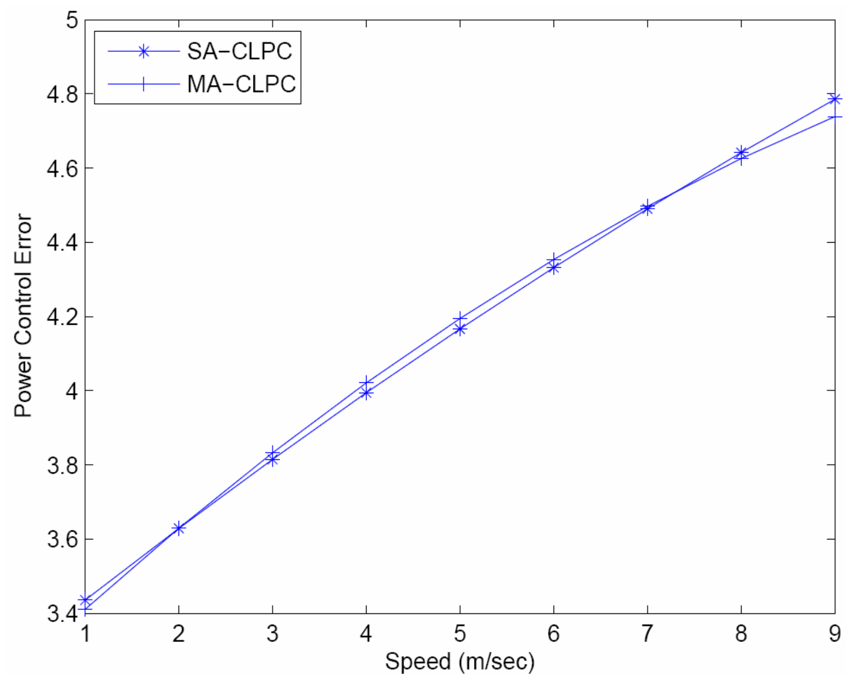

Figure 6. Power Control Error (PCE) of SA-CLPC and MA-CLPC under Motley-Keenan Indoor Propagation Model

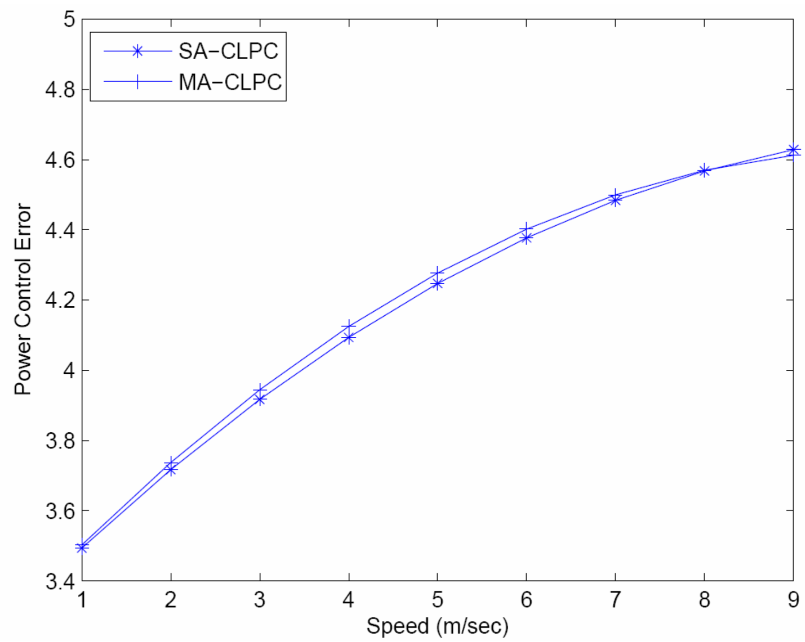

Figure 7. Power Control Error (PCE) of SA-CLPC and MA-CLPC under COST 231 Multiwall Indoor Propagation Model

6. Conclusion

The main focus of this paper is to study and analyze the performance of different power control methods in indoor propagation environment. For this purpose, four adaptive power control methods and three indoor propagation models selected from the literature. All four power control method have already been evaluated and compared, but only for outdoor propagation [6]. Results of our project simulation show that for unknown speeds AS-CLPC can perform better even in indoor propagation models. And in case of known speed SA-CLPC can be better option for indoor environments.

References

[1] J. Perez-Romero, O. Sallent, R. Agusti, and M. A. Diaz- Gurera. Radio Resource Management Strategies in UMTS. John Wiley and Sons, 2005.
[2] J. H. Kim, S. J. Lee, and Y. W. Kim. Performance of single bit adaptive step-size closed-loop power control scheme in DC-CDMA system. IEICE Trans. Commun., E81-B:15481552, Jul. 1998.
[3] S.Nourizadeh, P.Taaghol, and R.Tafazolli. A novel closed loop power control for umts. In IEE. Conf. on 3G Mobile Communication Technologies, pages 56–59, Mar. 2000.
[4] P. Taaghol. Speed-adapted power control for CDMA systems,. Bechtel Telecommunications Technical Journal, 2(1), Jan. 2004.
[5] H. Lee and D. Cho. A new user mobility based adaptive power control in CDMA systems. IEICE Trans. Commun., E86-B(5):17021705, May 2003.
[6] R. Patachaianand and K. Sandrasegaran. Performance comparison of adaptive power control in UMTS. In 2nd International Conference on Wireless Broadband and Ultra Wideband Communications, pages 81–85, 2007.
[7] D. M. J. Devasirvatham. A comparison of time delay spread and signal level measurements within two dissimilar office buildings. IEEE. Trans. Antennas Propagat., 35(3): 319– 324, 1987.
[8] F. Mikas, S. Zvanovec, and P. Pechac. Measurement and prediction of signal propagation for WLAN systems. Czech Technical University in Prague, 2002.
[9] COST231. Propagation prediction models. Final report, European Co-operation in the Field of Scientific and Technical Research, Chapter 4.
[10] H. Holma and A. Toskala. WCDMA for UMTS. John Wiley and Sons, 2000.

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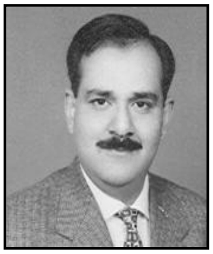

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