

# Quasi-optimum Power Control Scheme for Downlink in W-CDMA Cellular System

Bazil Taha Ahmed, Miguel Calvo Ramón, and Leandro de Haro Ariet

**Abstract**—The downlink power control problem in W-CDMA is studied using two new models. The downlink cell capacity is given for the old given by Gejji and our new models. A capacity increase of 6.8% for the special case  $\varphi = 0$  (no orthogonality between users) and a generalization of the old model are obtained using the second new model.

**Index Terms**—Downlink capacity, Power control, W-CDMA.

## I. INTRODUCTION

THE DOWNLINK power control problem in W-CDMA system is considered. This problem has been identified by Lee [1], and Gilhousen *et al.* [2], as an important issue of the capacity of the CDMA cellular system. The purpose of the downlink power control is to reduce the amount of the interference from the neighboring cells by reducing the total amount of power transmitted by the base station [3]. Since power control consists of reducing the share of power transmitted for the close-in users, it is possible that a power control law devised on the bases of the CIR of boundary users could put the close-in users in a disadvantage. A service hole could happen if the power control strategy is based on the need of the boundary users and the very close-in users. Thus the power control law should prevent the occurrence of service hole in the internal of the cell. When the power control is used in the downlink, the downlink capacity increases. The aim of this work is to present a quasi-optimum power control scheme for downlink in W-CDMA Cellular system and to study the downlink capacity for voice and data users.

## II. POWER CONTROL MODEL

We use the geometry shown in Fig. 1 to calculate the intracellular and intercellular interference from 19 cells of radius  $R$ . We assume that the user  $i$  is located within the home cell (cell 1) at a distance  $r$  from its base station. Using the old model [3], the transmitted power for a user at distance  $r$  from the base station is given as

$$P_i(r) = P_R f(r) \tag{1}$$

where  $P_R$  is the reference power level corresponding to the signal power transmitted for a user located at  $r = R$ , and  $f(r)$  is the power profile. In the old model  $f(r)$  is given by [3]

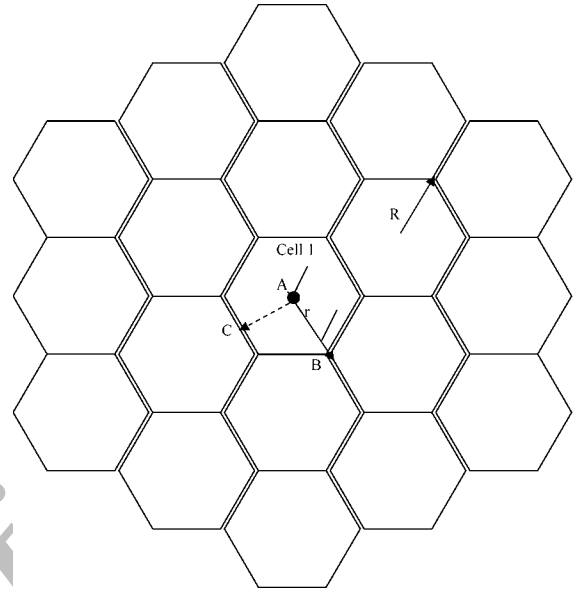


Fig. 1. The 19 cells model.

$$f_{old}(r) = \begin{cases} \left(\frac{r_o}{R}\right)^n & \text{for } r \leq r_o \\ \left(\frac{r}{R}\right)^n & \text{for } r > r_o \end{cases} \tag{2}$$

where  $P_i(r)$  is assumed to be proportional to the normalized distance raised to  $n$ , but every user located at a distance less than  $r_o$  is assured of a minimum amount of transmitted power.

For analytical convenience, hexagonal cells are approximated by circular cells with radius  $R$  [4]. Assuming a uniform distribution of  $N$  users in the cell, the users density  $\rho$  is:

$$\rho = \frac{N}{\pi R^2} \tag{3}$$

Since the real shape of the cells is circle then, the total power transmitted by the base station is

$$P_{Told} = \frac{N P_R}{\pi R^2} \int_0^{2\pi} \int_0^R f(r) r dr d\theta = \frac{2N\pi P_R}{\pi R^2} \int_0^R f(r) r dr \tag{4}$$

$$= N P_R \kappa_{old}$$

where

$$\kappa_{old} = \frac{2}{n+2} + \frac{n}{n+2} \left(\frac{r_o}{R}\right)^{n+2} \tag{5}$$

The drawback of this model is that the power assigned to users near to the cell center is more than the real need especially when users orthogonality exists. To solve this drawback we propose two new models in which the power

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 Authors are with the Departamento Sistemas, Señales y Radiocomunicaciones, ETSI Telecomunicación, Universidad Politécnica de Madrid, Ciudad Universitaria, Madrid, 28040, España. (e-mail: bazil@gr.ssr.upm.es)  
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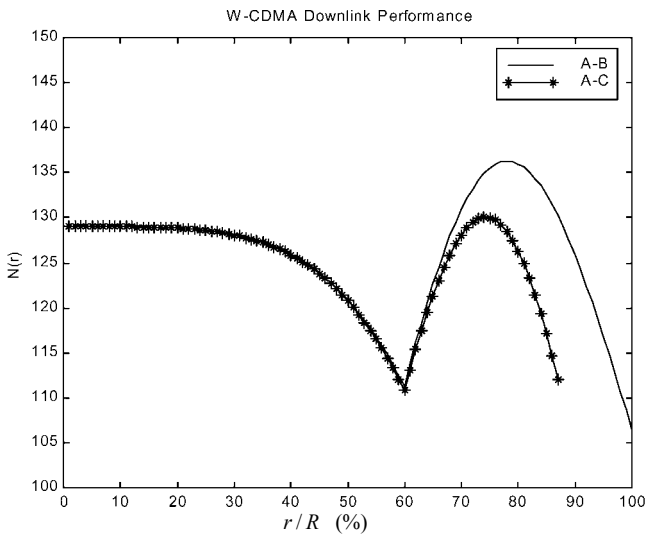


Fig. 2. The downlink sector capacity using the old model,  $\phi = 0$ ,  $n = 2$ , and  $r_o = 0.6R$ .

assigned to users near the center of the cell is reduced according to the system situation.

The power profile of the first new model is given by

$$f_{new1}(r) = \begin{cases} \left( a + b \left( \frac{r}{r_o} \right) \right) \left( \frac{r_o}{R} \right)^n & \text{for } r \leq r_o \\ \left( \frac{r}{R} \right)^n & \text{for } r > r_o \end{cases} \quad (6)$$

where

$$a + b = 1. \quad (7)$$

The total transmitted power factor ( $P_{Tnew1}$ ) is given as

$$P_{Tnew1} = NP_R \kappa_{new1} \quad (8)$$

where

$$\kappa_{new1} = a \left( \frac{r_o}{R} \right)^{n+2} + \frac{2b}{3} \left( \frac{r_o}{R} \right)^{n+2} + \frac{2}{n+2} - \frac{2}{n+2} \left( \frac{r_o}{R} \right)^{n+2} \quad (9)$$

The power profile of the second new model is given by

$$f_{new2}(r) = \begin{cases} \left( a + b \left( \frac{r}{r_o} \right)^{n1} \right) \left( \frac{r_o}{R} \right)^n & \text{for } r \leq r_o \\ \left( \frac{r}{R} \right)^n & \text{for } r > r_o \end{cases} \quad (10)$$

where  $n1 > 3$  and

$$a + b = 1. \quad (11)$$

The total transmitted power factor ( $P_{Tnew2}$ ) is given as

$$P_{Tnew2} = NP_R \kappa_{new2} \quad (12)$$

where

$$\kappa_{new2} = a \left( \frac{r_o}{R} \right)^{n+2} + \frac{2b}{n1+2} \left( \frac{r_o}{R} \right)^{n+2} + \frac{2}{n+2} - \frac{2}{n+2} \left( \frac{r_o}{R} \right)^{n+2} \quad (13)$$

It is worth mentioning that the old model is a special case of our two new models and can be given assuming  $a = 1$ . Our first new model is a special case of the second new model and it is convenient to be used when the propagation exponent is 2.

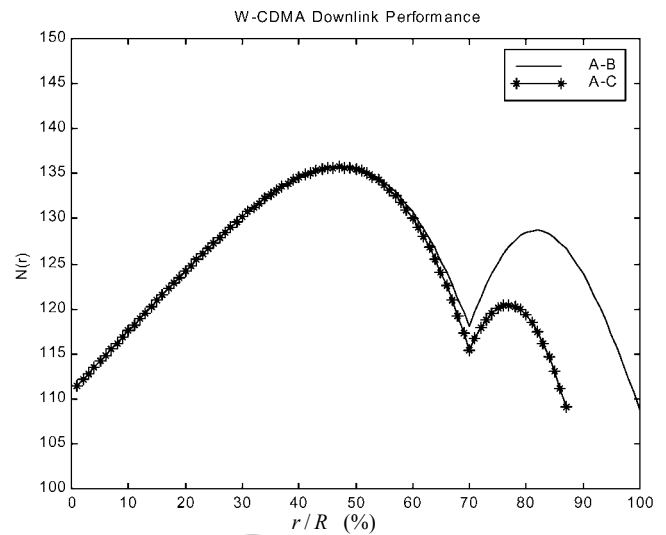


Fig. 3. The downlink sector capacity using the first new model,  $\phi = 0$ ,  $n = 2.35$ ,  $r_o = 0.7R$ , and  $a = 0.7$ .

### III. DOWNLINK CAPACITY

For the downlink, the ratio ( $E_b / N_o$ ) at distance  $r$  from the home cell base station is given by:

$$\frac{E_b}{N_o} = \frac{P_{ch} f(r) G_p}{\alpha \gamma(r) N \kappa} \quad (14)$$

where

- $P_{ch}$  is the power assignment for the users channels  $\approx 0.8$ ,
- $G_p$  is the W-CDMA processing gain,
- $\alpha$  is the source activity factor,
- $\gamma(r)$  is the downlink interference factor given by

$$\gamma(r) = (1 - \phi) + \sum_{j=2}^{19} \left( \frac{r}{R_{ij}} \right)^4 \quad (15)$$

where  $\phi$  is the orthogonality factor and  $R_{ij}$  is the distance between the user  $i$  and the base station  $j$ . The factor  $\gamma(r)$  increases from  $(1 - \phi)$  at  $r = 0$  to  $(3.36 - \phi)$  at  $r = R$  when the user is located along the line AB. Here the propagation exponent is assumed to be 4.

Then the capacity at a distance  $r$  is given by:

$$N(r) = \frac{P_{ch} f(r) G_p}{\alpha \gamma(r) (E_b / N_o)_{req} \kappa} \quad (16)$$

where  $(E_b / N_o)_{req}$  is the  $(E_b / N_o)$  ratio required to get a given bit error rate.

The downlink capacity ( $Cap_d$ ) is given as:

$$Cap_d = \min[N(r)] \quad (17)$$

### IV. NUMERICAL RESULTS

We will study the downlink capacity for different cases for both directions AB and AC shown in Fig. 1.

We assume the following for voice service:

- $G_p = 400$ ,
- $(E_b / N_o)_{req} = 5$  dB, and
- $\alpha = 0.5$  (voice users).

The old model assumes that the orthogonality factor  $\phi$  is 0. Therefore, we will examine this case using the three models. In [3], [4], the best result is obtained when  $n = 2$  and  $r_o = 0.6R$ . First, we examine the old model when

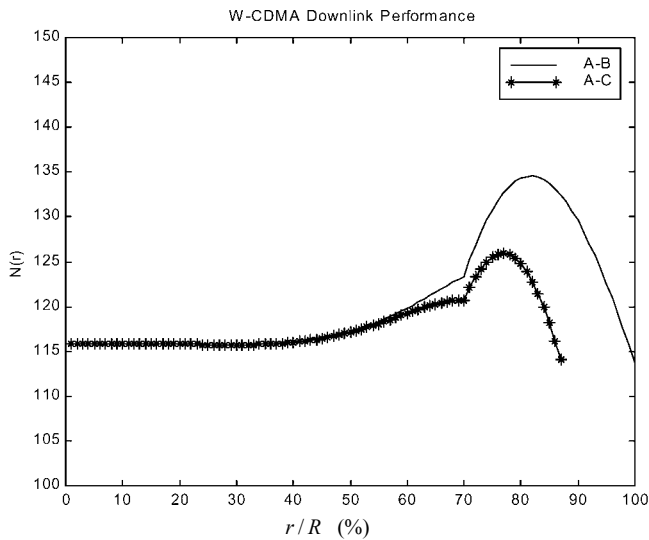


Fig. 4. The downlink sector capacity using the second new model,  $\phi = 0$ ,  $n = 2.35$ ,  $r_o = 0.7R$ ,  $a = 0.7$ , and  $n1 = 5$ .

$n = 2$  and  $r_o = 0.6R$ . From Fig. 2, the capacity using the old model is 106.5 users/cell. The power reduction factor ( $\kappa_{old}$ ) is 0.5648. The capacity profile shown in Fig. 2 is for both directions AB and AC.

Secondly we consider the case of our first new model. The best result is obtained when  $n = 2.35$ ,  $r_o = 0.7R$  and  $a = 0.7$ . Fig. 3 shows the capacity profile of the downlink for this case. The capacity using the first new model is 108.8 users/cell. The power reduction factor ( $\kappa_{new1}$ ) is 0.5531. This model gives a downlink capacity which is 102.16% of the old capacity.

Thirdly, we consider the case of our second new model. The best result is obtained when  $n = 2.35$ ,  $r_o = 0.7R$ ,  $a = 0.7$  and  $n1 = 5$ . Fig. 4 shows the capacity profile of the downlink for this case. The capacity using the second new model is 113.75 users/cell. The power reduction factor ( $\kappa_{new2}$ ) is 0.5288. This model gives a downlink capacity which is 106.8% of the old capacity. In [4], it was mentioned that the old model gives a result which is about 93% of the optimum one. Thus our second model is quasi-optimum model since it gives 6.8% more capacity.

Fourthly, we consider the case when  $\phi = 0.5$ . The new second model gives the best results when  $n = 2.3$ ,  $r_o = 0.9R$ ,  $a = 0.25$  and  $n1 = 6$ . Fig. 5 shows the capacity profile of the downlink for this case. The capacity using the second new model is 157.88 users/cell. The power reduction factor ( $\kappa_{new2}$ ) is 0.4476.

Next we assume the following for data service:

- $G_p = 26.6$ ,
- $(E_b / N_o)_{req} = 4$  dB, and
- $\alpha = 1$ .

Fig. 6 presents the downlink capacity profile for data users when  $\phi = 0.5$ . In this case the downlink capacity is 6.66 data users.

We have to mention that the old model can not be compared with the new ones when the orthogonality factor is 0.5 since it assumes that the orthogonality factor is 0.0 (another drawback of the old model) and its results is the same as given in Fig. 2 whatever is the orthogonality factor.

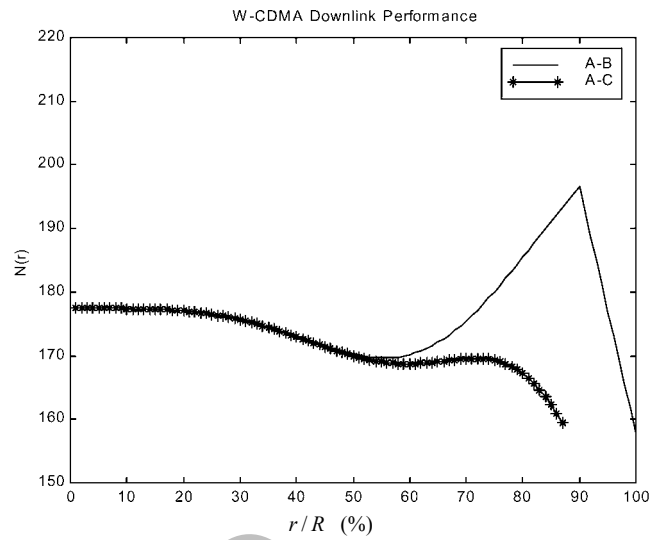


Fig. 5. The downlink sector capacity using the second new model,  $\phi = 0.5$ ,  $n = 2.3$ ,  $r_o = 0.9R$ ,  $a = 0.25$ , and  $n1 = 6$ .

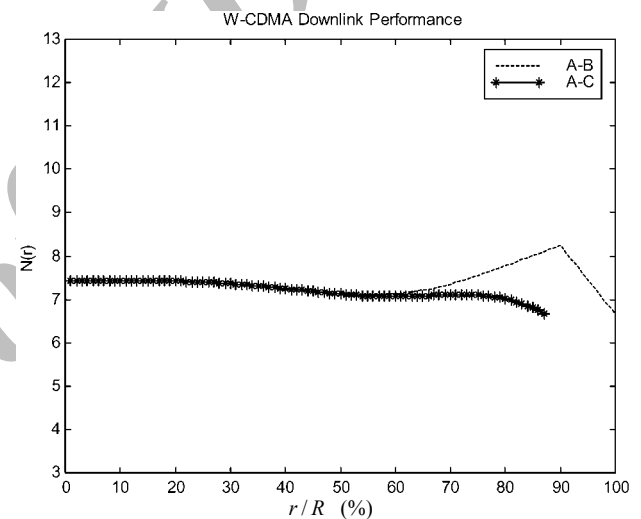


Fig. 6. The downlink sector capacity for data users using the second new model,  $\phi = 0.5$ ,  $n = 2.3$ ,  $r_o = 0.9R$ ,  $a = 0.25$ , and  $n1 = 6$ .

V. CONCLUSIONS

A new two models for the W-CDMA downlink power control is proposed and the downlink cell capacity is compared for the old and new cases. A 6.8 % increase in the cell capacity is obtained using the second new model for the case of non-orthogonal users. The new models generalize the old one. The second new model is quasi-optimum power control model.

REFERENCES

- [1] W. C. Y. Lee, "Overview of cellular CDMA," *IEEE Trans. Veh. Technol.*, vol. 40, no. 2, pp. 291-302, May 1991.
- [2] K. S. Gilhousen, L.A. Weaver, and C.E. Wheatly, "On the capacity of a cellular CDMA system," *IEEE Trans. Veh. Technol.*, vol. 40, no. 2, pp. 303-312, May 1991.
- [3] R. R. Gejji, "Forward-link power control in CDMA cellular systems," *IEEE Trans. Veh. Technol.*, vol. 41, no. 4, pp. 532-536, Nov. 1992.
- [4] W. -M. Tam and F. C. M. Lau, "Analysis of power control and its imperfections in CDMA cellular systems," *IEEE Trans. Veh. Technol.*, vol. 48, no. 5, pp. 1706-1717, Sep. 1999.

**Bazil Taha Ahmed** was born in Mosul, Iraq, in 1960. He received the B.Sc. and M.Sc. degrees in communication engineering from the University of Mosul, in 1982 and 1985, respectively.

From 1985 to 1998, he was teaching at the Electrical Engineering Department at Mosul University.

Now he is doing his Ph.D. study at the Technical University of Madrid. His research interests include W-CDMA capacity and electromagnetic wave propagation in micro-cellular and macro-cellular environments.

**Miguel Calvo Ramón** was born in Pueyo de Jaca, Huesca, Spain in 1949. He received the M.Sc. and Ph.D. both in telecommunications from the Universidad Politécnica de Madrid in 1974 and 1979, respectively. He is presently a Professor in the Signals, Systems and Radiocommunications Department in the same university since 1986.

Since his incorporation to the University in 1974 he has worked in a number of projects in the areas of numerical methods in electromagnetics, electromagnetic compatibility, communication systems and satellite communications.

Since 1998 he has participated as a delegate in the ITU-R TG8.1 meetings that developed the IMT-2000 standards and in the follow up ITU-R WP8F for upgrades and systems beyond IMT-2000.

He was a Research Visitor at Queen Mary College, London University in 1983 and Technical Visitor at Nichols Center, Kansas University in Lawrence in 1993. he has co-authored a number of papers in technical reviews and contributed in a number of international conferences. He wrote a chapter in the book "Reflector and Lens Antennas. Analysis and Design using Personal Computers", C. J. Sletten editor, Artech House 1988, contributed two chapters in "Modelling and Simulation environment for Satellite and Terrestrial Communication Networks," Kluwer Academic Publishers 2002, and edited "Sistemas de Comunicaciones Móviles de Tercera Generación IMT-2000 (UMTS)," Fundación Airtel-Vodafone 2002.

**Leandro de Haro Ariet** was born in Barcelona, Spain, in 1962. He received the M.Sc. and Ph.D. both in telecommunication from the Universidad Politécnica de Madrid in 1986 and 1992, respectively.

Since 1990 he develops his professional career in the Signals, Systems and Radiocommunications Department of the Universidad Politécnica de Madrid as an Assistant Professor.

His research interests include antenna design for satellite communications, satellite communication systems and Study and design of digital TV communication systems. He has been actively involved in several research projects in cooperation with public and private companies. He has also been involved in several European projects.

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