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WCDMA Common Pilot Power Control with Cost Function Minimization

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Abstract – **This paper validates the feasibility of automating the setting of common pilot power in a WCDMA radio network. The pilot automation improves operability of the network and it is implemented with control software aiming for load balancing while also assuring pilot coverage. The pilot power of a cell is periodically updated with a gradient descent method that minimizes a cost function. The cost function describes differences in load between the cell and neighboring cells and pilot coverage that terminals of the cell measure. The approach was validated using a dynamic WCDMA system simulator with a deployment of macro and micro cells on a city region whose measured propagation characteristics were incorporated into the model. The results showed that the proposed control method slightly improved the air interface performance measured as a function of packet throughput.**

I. Introduction

The WCDMA radio interface for third generation mobile networks can carry voice and data services with various data rates, traffic requirements, and quality-of-service targets [2]. Moreover, the operating environments vary considerably from indoor cells to large macro cells. Efficient use of limited frequency spectrum in diverse conditions requires careful setting of numerous vital network and cell parameters such as maximum load levels and allocated channel powers. The parameter setting is referred to as radio network planning and optimization. Once a WCDMA network is built and launched, its operation and maintenance largely consists of monitoring the performance or quality characteristics and changing parameter values in order to improve performance. The operability of the network would considerably benefit from automated monitoring and parameter changing. WCDMA network autotuning and advanced monitoring are discussed in [7].

This paper addresses the control of the common pilot power whose value is a cell-specific parameter. In the Universal Mobile Telecommunications System, the terminal measures and reports the received level of the pilot energy-per-chip-to-total-wideband-interference-density ratio, or E_c/I_0, for the handover cell selection. The pilot power determines the cell coverage area and the average number of terminals connected to the cell. Increasing or decreasing the pilot power makes the cell larger or smaller. Thus, the adjusting of pilot powers can be applied to balance the cell load among neighboring cells, which reduces the variation of interference, stabilizes the network operation, and facilitates the radio resource management. Previous pilot power studies have been reported in [6], [10], and [13], for instance.

The pilot control method is verified with an advanced WCDMA radio network simulator developed at Nokia Research Center in Helsinki [3]. The simulator models 32 macro cells and 46 micro cells deployed over an area of Helsinki center. A set of mobile terminals move in the area with constant speed and, with random intervals, make downlink packet-switched calls of variable bit rates. The packet-switched service is selected because packet throughput is a simple and descriptive measure of the air interface performance. Only the downlink (forward link) is simulated, since it is assumed to be the limiting link. The simulator implements many advanced features such as packet scheduler, admission control, closed-loop and outer-loop power controls, soft and hard handover controls, and load control. Previous studies with the simulator are described in [1,8,13].

II. Method

A. Measuring downlink load

The cell load is measured as the ratio of total transmission power to the target transmission power. The target transmission power is the planned level at which the cell resources are considered to be in optimum use in downlink [7]. The target power depends on the maximum transmission power of the base station and differs among macro cells and micro cells. The cell load is thus commensurate among different cell layers. As the capacity is more limited in downlink than in uplink [2], we see that the measuring of the downlink load only suffices for our purpose.

The load is sampled separately for each cell. Logarithms of the sample values are taken. The cell keep two counters. The first collects the number of samples and the second collects the sum of the sample values. Denote the counter values of cell i by N_I and S_i, respectively. The counters are reset at the point of pilot power adjustment. The sample mean of the load in cell k is obtained with equation

$$m_1 = \frac{S_k}{N_k} \tag{1}$$

The statistics for the load in the neighboring cells is obtained with

$$m_2 = \frac{\sum_i S_i}{\sum_i N_i},\ i \neq k \tag{2}$$

The load statistic is defined as

$$loadStatistic = \frac{m_1}{m_2} - 1 \tag{3}$$

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B. Measuring pilot coverage

The terminals in the cell report the received E_c/I_0 of the pilot as event-triggered handover reports in the cell border area or when they reach the cell soft handover area. For each reported E_c/I_0, cell-specific counter N_{ecio} is incremented. If E_c/I_0 exceeds –18 dB, counter N_{over} is also incremented. The specifications of the Third Generation Partnership Project require that the terminal must be able to decode the pilot from a signal with E_c/I_0 of –20 dB [12, 13]. The –18-dB threshold is used to leave a margin for safety, although quality receivers can cope with ratios several decibels lower than –20 dB. The counters are reset at the point of pilot power adjustment. The coverage statistic is obtained with formula

$$covStatistic = \frac{N_{\mathrm{over}}}{N_{\mathrm{ecio}} \cdot coverageTarget} - 1, \qquad (4)$$

in which *coverageTarget* was set to 0.98, that is, the target was that 2% of the event-triggered handover E_c/I_0 measurements in the cell border area were below –18 dB.

C. Autotuning algorithm

The algorithm applies the gradient descent method to the minimization of a cost function that describes two items: the deviation of the coverage from the target and the deviation of the load from the load in the neighboring cells. The statistics are weighted with *LW* and *CW*. The value of cost function is obtained as

$$\begin{aligned} C = {} & LW \cdot \mathrm{abs}(loadStatistic) + \\ & CW \cdot \mathrm{abs}(\min(covStatistic, 0)) \end{aligned} \qquad (5)$$

In the simulations, the weights were set to $LW = 0.1$ and $CW = 1$, which produced equal weighting in the sense that the variances of the two terms of equation (5) were similar. The cost function obtains the minimum when the load statistic is zero and the coverage statistic is zero or any value above. The gradient descent method is used to adjust the pilot power, p, in order to minimize the cost:

$$\Delta \log p = -0.001 \frac{\Delta C}{\log p_{old} - \log p_{older}}. \qquad (6)$$

$$p_{new} = e^{\Delta \log p}\, p_{old}, \qquad (7)$$

in which p_{old} and p_{older} are the two previous pilot levels given in watts. If pilots p_{old} and p_{older} were equal, that is, no pilot adjustment was made because the change in cost was zero, the descent would fail with division by zero. When the case of unchanged pilot occurs, the pilot power is decreased by one percent, that is,

$$p_{new} = 0.99 \cdot p_{old}, \qquad (8)$$

in order to prevent the deadlock.

III. Simulation Parameters

Figure 3 shows the general view of the simulated network. Green bars depict cells by pointing to the principal direction of antenna pattern, except for cells with omni directional antennas that are vertically depicted. The channel multipath profile was that of ITU Vehicular A [11] with 5-path propagation. The path gains are shown in Table II. One half of the signal power came along the line of sight and the other half was a sum of powers from four reflected signals. Signals from the same base station propagating along the same path were totally orthogonal; that is, they did not interfere with each other. Thus, the downlink orthogonality factor [2] computed from the path gains was 60%. The propagation loss was calculated using the Okumura-Hata model [9] with average correction factor of –6.2 dB. The shadow fading process conformed to the buildings, streets, and water areas (Fig. 3). Short-term fading with 7-dB deviation was added to the process. The fast fading process was that of Jakes [5]. The simulation step was one frame or 10 ms, at which the transmission powers, received interference, and signal-to-interference ratios were recalculated for each connection in the downlink. The method of [4] was used to obtain the correctness of received frames from signal-to-interference ratios. The mobile stations were uniformly distributed along the streets of the simulated area and they made new calls according to a Poisson interarrival distribution. The packet sizes of calls were generated according to a Pareto distribution. The call parameters were selected to fill the system up to the target level of the downlink transmission power. The simulation time was 300 seconds. In the simulations, the planned pilot power was 1 W in the macro cells and 200 mW in the micro cells, that is, 5% of the maximum base station power [7, p. 263].

TABLE II
NETWORK PARAMETERS

Parameter	Value
Chip rate	3.84 MHz
Frequency	2.0 GHz
Bandwidth	5.0 MHz
Base station maximum transmission power	macro cell 20 W, micro cell 4 W
Power control dynamic range in downlink	20 dB
Maximum link power in downlink	1 W
Base station antenna sector and gain	65°, 17.5 dBi Omni, 11.0 dBi
Mobile station antenna sector and gain	Omni, 0.0 dBi
Downlink system noise	–99.9 dBm
Minimum coupling loss	–50 dB
Average antenna height	18 m
Multipath propagation gains	50, 30, 11, 6, 3 %
Mobile station speed	3 km/h
Number of mobile stations	10,000
Call arrival rate for a mobile station	120 h^{-1}
Mean no of packets in downlink packet call	50
Mean packet size in downlink packet call	3.8 kilobits
Packet bit rates	8, 12, 64, 144, 512 kb/s
Outer loop FER target	10 %
Admission control and packet scheduler transmission power target	macro cell 10 W, micro cell 2 W
Handover control add window	1 dB
Handover control drop window	3 dB

IV. Results and Discussion

Table III shows the downlink packet performance measures obtained with and without the autotuning. The performance improved slightly but the improvement was not practically significant. The results described in our previous study [13], whose control method applied simple heuristic rules, showed better performance. Table IV shows that the downlink total transmission powers (PtxTotal) were similar with and without the autotuning. As the target pilot coverage was 98%, the results in Table IV shows that the coverage deteriorated with the autotuning. The distributions of the coverage measures are shown in Figs 1 and 2. The coverage could be improved by increasing its weight in the cost function (5). Figure 3 shows the distribution of the load statistic in the end of the simulation with the control method. The load differences were mostly within 20%.

To conclude, the control method improved the air interface performance slightly by minimizing a cost function containing coverage and load statistics. The method can improve the network operability with its automation and allow the operator to optimize pilot power with respect to a certain load balancing and pilot coverage prioritization.

TABLE III
PACKET PERFORMANCE RESULTS

	Improvement with autotuning
Total throughput	1%
Active session throughput	5%
Allowed bit rate	9%
95th packet delay percentile	2%

TABLE IV
PERFORMANCE RESULTS

	No Autotuning	Autotuning
Macro PtxTotal (std) [W]	9.0 (2.0)	8,8 (2.2)
Micro PtxTotal (std) [W]	1.9 (0.3)	1.9 (0.3)
Macro pilot power (std) [W]	1 (0)	1.0 (0.4)
Micro pilot power (std) [W]	0.2 (0)	0.2 (0.09)
1 – macro coverage [%]	1.6	2.8
1 – micro coverage [%]	1.3	2.4

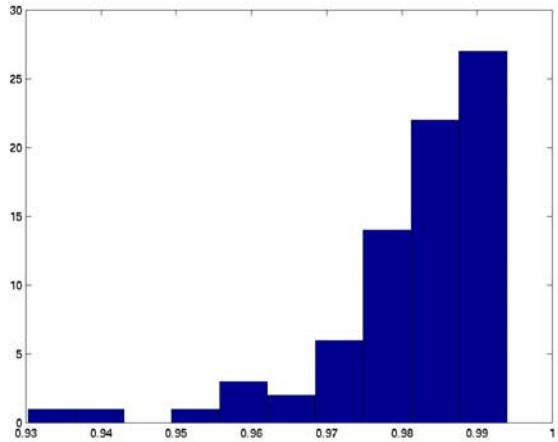

Fig. 1: A histogram of the coverage of the 78 cells in the end of the simulation without the load-balancing algorithm.

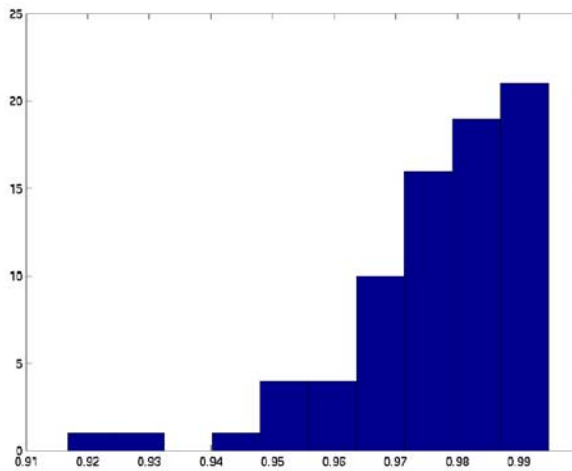

Fig. 2: A histogram of the coverage of the 78 cells in the end of the simulation with the load-balancing algorithm.

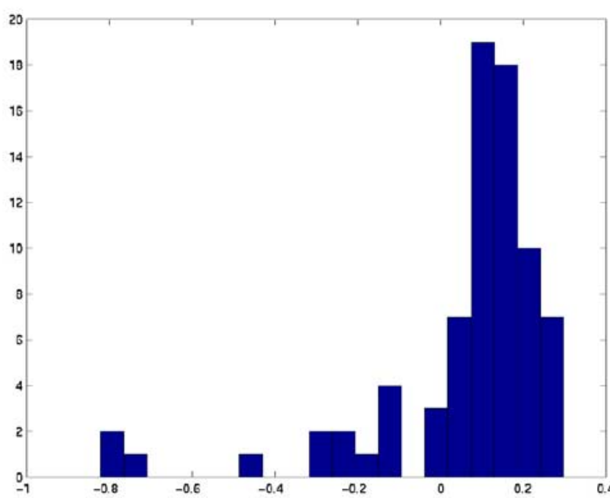

Fig. 3: A histogram of the load statistics (3) in the end of the control simulation.

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REFERENCES

[1] T. Buot, H. Zhu, H. Schreuder, S. Moon, B. Song, and T. Eriksson, "Soft handover optimization for WCDMA". *Proc. 4th Int. Symp. on Wireless Personal Multimedia Communications*, Aalborg, Denmark, pp. 141-146, September 2001.

[2] H. Holma and A. Toskala, Eds, *WCDMA for UMTS*. Wiley and Sons, 2001.

[3] S. Hämäläinen, H. Holma, and K. Sipilä, "Advanced WCDMA radio network simulator", *Proc. PIMRC,* Aalborg, Denmark, pp. 509-604, October 1999.

[4] S. Hämäläinen et al., "A novel interface between link and system level simulations", *Proc. ACTS Summit*, Aalborg Denmark, pp. 599-604, October 1997.

[5] W. C. Jakes, Microwave Mobile Communications. New York: Wiley and Sons, 1974

[6] D. Kim, Y. Chang, and J.W. Lee, "Pilot power control and service coverage support in CDMA mobile systems", *Proc. IEEE VTC*, Houston, TX, pp.1464-1468, May 1999.

[7] J. Laiho, A. Wacker, and T. Novosad, Eds, *Radio Network Planning and Optimisation for UMTS*. West Sussex, England: Wiley and Sons, 2002.

[8] J. Laiho, A. Wacker, T. Novosad, and A. Hämäläinen, "Verification of WCDMA radio network planning prediction methods with fully dynamic network simulator", *Proc. IEEE VTC*, Atlantic City, NJ, pp. 526-530, October 2001.

[9] J. Lee and L. Miller, *CDMA Systems Engineering Handbook*. London: Artech House, 1998.

[10] R.T. Love, K.A. Beshir, D. Schaeffer, and R.S. Nikides, "A pilot optimization technique for CDMA cellular systems", *Proc. IEEE VTC*, Amsterdam, The Netherlands, pp. 2238-2242, 1999.

[11] Universal Mobile Telecommunications System (UMTS): "Selection procedures for the choice of radio transmission technologies of the UMTS", TR 101 112 V3.1.0 (1997-11), UMTS 30.03 version 3.1.0. UMTS30.03

[12] Third Generation Partnership Project (3GPP): "Requirements for support of radio resource management". Technical Specification 25.133, v5.00, 2001.

[13] K. Valkealahti, A. Höglund, J. Parkkinen, and A. Hämäläinen, "WCDMA common pilot power control for load and coverage balancing". *Proc. 13th IEEE PIMRC*, Lisbon, Portugal, 2002. To be published.

[14] R.G. Akl, M.V. Hedge, M. Naraghi-Pour, P.S. Min, "Cell placement in a CDMA network". *Proc. IEEE Wireless Communications and Networking*, Vol 2, pp. 903-907, 1999.

Fig. 4: Deployment of 32 macro cells and 46 micro cells in Helsinki center area.