Other-Cells Interference in CDMA Systems

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Abstract: Using simulation and modelling, the other-cells interference factor for CDMA systems is obtained. Situations with tiers of neighbouring cells are investigated under various propagation parameters and for two scenarios, when the mobile chooses the nearest base station, and when it chooses the base station with the strongest signal as home cell. The results presented indicate that in most situations the other-cells interference factor can be significantly less than the *upper bounds* result published previously. It is concluded that it is enough to compare the link attenuation of three neighbouring cells to find the home cell.

Introduction: Mobile communications has enjoyed rapid growth during the last decade. However the available spectrum available is limited and consequently capacity planning is an important issue in cellular systems design. In CDMA all calls interfere with one another as they all use the same frequency range, and system capacity decreases with the amount of interference. Each base station not only receives interference from the mobiles in the home cell (intra-cell interference) but also from mobiles located in neighbouring cells (inter-cell interference). A detailed knowledge of parameters affecting the capacity and hence interference is therefore required for close system design. In [1] an *upper bound* for other-cells interference factor (the ratio of inter-cell interference to intra-cell interference) was presented using analytical methods. Such a parameter is commonly used in calculations to approximate other-cells interference [2]. In this letter, simulation and modelling is used to determine the other-cells interference factor and the results are compared with the upper bounds result in [1]. The effect of propagation parameters on other-cells interference factor is also investigated.

System Model: Consider a cellular CDMA network (a home cell and tiers of neighbouring cells) with a base station located at the centre of each cell. In successive simulations additional tiers of neighbouring cells are added until any further addition has very little effect. The simulation results indicated that it is enough to consider three tiers of neighbouring cells. It is assumed that all cells are homogeneous in every respect and users are uniformly distributed over the cell area. Only the reverse link (from mobile to cell site) is considered as it is the limiting link due to its inferior performance compared to forward link.

The other-cells interference factor (*f*) can be calculated as the ratio of other-cells interference αI_o to within-cell interference $\alpha(N-1)S$ [4].

$$f = \frac{\alpha I_o}{\alpha(N-1)S} = \frac{I_o / S}{N-1} = \frac{\sum_{i=1}^{M}\sum_{j=1}^{N}[I_o / S]_{ij}}{(N-1)}$$

$$(I_o / S)_{ij} = (r_m / r_o)^m 10^{\xi_o - \xi_m / 10}$$

where the system model and I_o/S calculations are explained in greater detail in [3].

In above equation, I_o is the interference produced by all users who are power controlled by base stations other than the home base station, S is the received signal strength at the home base station, α is the voice activity ratio, N is the number of active users per cell, M is the number of outer cells, r_m and r_o are the distances from a random position to the corresponding closest base station and the neighbouring cell, m is the path loss exponent, ξ_m and ξ_o are lognormal (Gaussian in dB) random variable distribution with zero mean and standard deviation σ_ξ representing shadowing parameter in closest and neighbouring cell. Note that total showing is $\sigma_T = \sigma_\xi \sqrt{2}$. (The propagation model used assumes that attenuation is proportional to the product of the *m*th power of the distance and a lognormal random number (ξ) with mean zero and standard deviation of σ_ξ dB.)

The simulation results are obtained for two scenarios: (a) when the home cell is the closest cell ($r_m<r_o$); (b) when the home cell is the cell that provides the least attenuation [4]:

$$(r_m / r_0)^m 10^{\xi_0 - \xi_m / 10} \le 1$$

If the above ratio is greater than one, the mobile chooses the neighbouring cell, with the distance r_o to the mobile, as the home cell.

Results: The simulation is performed for one million arrivals and on each arrival, the other-cells interference factor is determined. These values are then averaged over the simulation period. Note that the value of *S* (power received at base station assuming perfect power control) is not required when calculating the other-cells interference ratio.

Tables 1 and 2 show relative other-cells interference factor. *f* is the other-cells interference factor obtained in this study, and *B* is the upper bounds values obtained in [1]. N_c is the number of base stations a mobile communicate with to find the best base station (N_c=1 signifies that the mobile chooses the closest cell while N_c=2 signifies that the mobile compares the attenuation received from two base stations and chooses the one with the lower attenuation as its home cell.)

The results obtained via simulation appear to be smoother than the upper bounds obtained analytically in [1]. For N_c=1, changing total shadowing from 10dB to 12dB has changed *B* from 6.23 to 20 while the simulation model indicated change of *f* from 2.28 to 4.14.

	N_c=1		N_c=2		N_c=3		N_c=4		N_c=5	
σ_T (dB)	*f*	*B*	*f*	*B*	*f*	B	*f*	*B*	*f*	*B*
2	0.50	0.49	0.44	0.43	0.43	0.43	0.42	0.43	0.41	-
4	0.60	0.67	0.46	0.47	0.43	0.45	0.42	0.45	0.41	-
6	0.84	1.14	0.48	0.56	0.45	0.49	0.43	0.49	0.42	-
8	1.32	2.40	0.52	0.77	0.48	0.57	0.46	0.55	0.45	-
10	2.28	6.23	0.57	1.28	0.52	0.75	0.50	0.66	0.49	-
12	4.14	20.00	0.60	2.62	0.55	1.17	0.53	0.91	0.51	-

Table 1: Other-cells interference factor for *m*=4

	N_c=1		N_c=2		N_c=3		N_c=4		N_c=5	
m	*f*	*B*	*f*	*B*	*f*	B	*f*	*B*	*f*	*B*
3.0	2.54	-	1.05	1.60	0.98	-	0.95	-	0.93	-
3.5	1.76	-	0.72	-	0.67	-	0.65	-	0.63	-
4.0	1.32	2.40	0.52	0.77	0.48	0.57	0.46	0.55	0.45	-
4.5	1.05	-	0.40	-	0.37	-	0.35	-	0.34	-
5.0	0.88	-	0.32	0.47	0.29	-	0.28	-	0.27	-

Table 2: Other-cells interference factor for σ_T=8dB

The simulation results confirm the results in [1] that by choosing N_c=2 a significant improvement in interference can be achieved compared to N_c=1. In table 1, for differential shadowing parameter of 8dB, the other-cells interference factor will reduce from f=1.32 (N_c=1) to 0.52 (N_c=2). The relative improvement in using the best of three cells as home cell is less but still noticeable (f=0.48 for N_c=3). Adding any further number of neighbouring cells have little effect on the other-cells interference factor (0.46 for N_c=4 and 0.45 for N_c=5). It is also noted that the effect of the value of N_c on other-cells interference are more significant in high shadowing and low distance exponent environment.

Note that using the upper bound results of [1] will result in higher interference and lower system capacity than actual due to higher other-cells interference factor. The above table provides an other-cells interferences factor (f) that could be used to provide a better understanding of capacity issues in CDMA systems.

The results further determine the extent by which the other-cells interference increase with the shadowing parameter but decrease with the distance exponent. It is concluded that the distance exponent has more effect than the shadowing parameter on other-cells interference. For example for N_c=3, changing total shadowing from 8dB to 10dB will increase the other-cells interference factor from 0.48 to 0.52 for m=4 (table 1), while changing the distance exponent from 4 to 5 will decrease the other-cells interference factor from 0.48 to 0.29 for σ_T=8dB (table 2).

Conclusions: Using simulation and modelling, the other-cells interference factor is determined under various propagation parameters and the results were compared with the upper bounds obtained analytically. It is concluded that the upper bounds could be much higher that the other-cells interference. As other-cells interference factor is commonly used in approximating the other-cells interference, the upper bound results obtained in earlier studies could result in lower system capacity than the actual capacity. A significant drop in attenuation and hence interference will result if we use the least attenuation cell as home cell compared to the closest cell. The most significant drop in other-cells interference is when shifting from the closest cell (as home cell) to the lower attenuation of two cells. The effect of adding the third base station is noticeable but less significant. It is concluded that it is enough to compare the attenuation of three neighbouring cells to find the home cell. When comparing the propagation parameters, the distance exponent has the dominant effect on other-cells interference.

References

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