THROUGHPUT IMPROVEMENT UNDER NETWORK LOAD ON FORWARD LINK INTER-CELL INTERFERENCE

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Abstract

A system with more throughput under the impact of network load in the neighboring sectors on the inter-cell interference in a cellular data network is proposed. The signal received by a user over the forward link in such a system contains interference from the neighboring base stations. The proposed scheme provides a more accurate estimate of the user SINR by taking better account of the contribution of inter-cell interference. It builds on top of the current SINR measurement scheme by using a combination of pilot measurement and traffic load measurement. With the proposed scheme a mobile terminal reports an accurate SINR and the same is informed to the base station. Hence the base station increases the data rate and hence the mobile terminal receives a higher throughput. The scheme especially benefits the "poor" user, i.e., the users that receive low throughput because they are located far from the base station. In this paper we prove that the data rate is increased for the poor users if the inter cell interference is low and hence the increase in the throughput of individual 'poor' mobile users.

Keywords: SINR, Network load.

I. INTRODUCTION

CDMA is a form of Direct Sequence Spread Spectrum communications. In general, Spread Spectrum communications is distinguished by three key elements:

1. The signal occupies a bandwidth much greater than that which is necessary to send the information. This results in many benefits, such as immunity to interference and jamming and multi-user access, which we'll discuss later on.
2. The bandwidth is spread by means of a code which is independent of the data. The independence of the code distinguishes this from standard modulation schemes in which the data modulation will always spread the spectrum somewhat.
3. The receiver synchronizes to the code to recover the data. The use of an independent code and synchronous reception allows multiple users to access the same frequency band at the same time.

In order to protect the signal, the code used is pseudo-random. It appears random, but is actually deterministic, so that the receiver can reconstruct the code for synchronous detection. This pseudo-random code is also called pseudo-noise (PN) .The extent of inter-cell interference experienced by a terminal is a function of the network load on the forward link of the neighboring cells. Hence the interference is higher(and the data rate is lower)when the network loads on the interfering forward links are higher and vice versa. The goal of this work is to analyze the cross-layer impact on the physical layer of a terminal in the given cell due to the loads at the network layer of the neighboring cell and to design a system with modified SINR. The SINR implementation is performed on pilot signal transmitted in a synchronous fashion by all base station. In this scheme, the SINR is estimated in a way equivalent to assuming that the forward links of the interfering cells are always busy.

II. CHARECTERIZING THE INTER-CELL INTERFERENCE

We consider here the SINR estimation scheme that uses synchronous pilot transmission by any base station, a CDMA-HDR SYSTEM[13].In such a system, data users are served over a data channel. There is no voice users in the systems.(fig1)

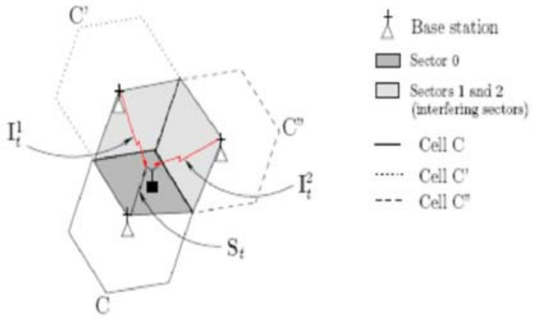

Fig. 1. Inter-cell interference

Let R be the radius of the sector. The base station uses a directional antenna for each of the three sectors, and hence we assume that there is no interference from the adjacent sectors of the same cell. However, a user in a given sector receives inter-cell interference from the neighboring sectors of the adjacent cells. The users in each sector are over the forward link in a TDM fashion using all the available power and bandwidth. The forward link is time domain multiplexed into time slots. The forward link waveform can be modeled as an ON-OFF process. During the ON time, i.e., during a busy time slot, the base station sends a sequence of +1 and -1 pulse. During the OFF time, i.e., during an idle time slot, there is no signal. Hence the interference experienced by a user because of this modified ON-OFF process. The higher the forward link traffic load in the neighboring sector to the user in the given sector.

Referring to fig .1 consider a terminal located in sector 0, and let the total forward link inter-cell interference at the terminal as a function of time t be I_t.Through simple geometric arguments, it is easy to show that the ratio of the distance from the edge of the cell to other interfering base station (not the two nearest interfering base stations), is at least twice the distance from the edge of the cell to two nearest base station. Hence, the interference from farther base station is weaker than the interference from the two nearest base station by at least a factor of 2^n., where n is the propagation loss exponent. We therefore only consider inter-cell interference from the two neighboring sectors, sectors 1 in cell C', and sector 2 in cell C''. However, all our results can be easily generalized to the case of multiple interfering sectors. The signal received at the terminal is:

$$R_t = S_t + I_t + N_t$$

Where N_t is the zero mean Gaussian noise at the receiver, and S_t is the desired signal. We also have

$$S_t = G0\, A \sum Y_n\, h(t-nT_c)\cos\omega_0 t \qquad (1)$$

Where Y_n €{+1,-1}is the transmitted symbol sequence, G_0 is the forwarded link channel gain from the base station of serving sector 0 to the terminal, A is the signal amplitude, and h(t) is a pulse of width T_c. In (1),$f_0 = \omega_0/2\pi$ is the carrier frequency, and we assume that $f_0 >> 1/T_c$.Let T be the duration of a time slot.(Referring to Fig.2)

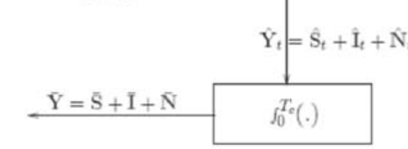

Fig. 2. Block diagram of simple correlation receiver

The components with a bar are the matched filter outputs of the corresponding input components with a hat. our objective is a determine the variance of the inter-cell interference component, I, so as to evaluate the SINR at the receiver.

We first consider inter-cell interference from a single interfering sector. Since the analysis dealing with the derivation of the variance of the inter-cell interference is technical in nature. The variance of the single inter-cell interference components is given by the following expression.

$$\sigma^2 = 1/3\, G^2 A^2 \rho_1 T_c^2 \qquad (2)$$

Where G_1 is the channel gain from the base station of the interfering sector to the terminal and ρ_1 is the traffic load on the forward link of that sector .Or equivalently, ρ_1 is the probability that a time slot on the forward link of the sector is busy.Thus,the intensity of the forward link traffic in the neighboring sector has a role to play in determining the variance of the inter-cell inference. With multiple inter-cell interference components, we note that the data stream and the channel gain of different BSs are independent, and hence we can add the variance due to noise,σ_N^2,is simply $2N_0T_c$.The total variance of the output is

$$\sigma^2 = 1/3A^2T_c^2(G_1^2\rho_1 + G_2^2\rho_2) + 2N_0T_c \qquad (3)$$

where ρ_i is the forward link traffic load of the ith interfering sector. If we assume that the desire signal transmitted by the BS of sector 0 is x(t)=Ah(t),then the mean of the output decision variable,m is :

$$m = \int_0^{T0} G_0 A\, h(t)h(t)\, dt$$

$$= G_0 A T_c$$

Hence the SINR at the output of the filter is given by:

$$\mathrm{SINR} = \frac{G_0^2 A^2 T_c}{\frac{1}{3}A^2 T_c(G_1^2\rho_1 + G_2^2\rho_2) + 2N_0} \qquad (4)$$

This is the expression for the SINR at s terminal in the presence of inter-cell interference from adjacent sectors.

III. NETWORK LOAD AND SINR

In the actual implementation of CDMA –HDR[13],the terminal measures the pilot signal transmitted periodically by the base station to determine the current SINR. This SINR value is then used to predict the supportable forward link data for that terminal for the next time slot. However, all the BSs are GPS–synchronized. Hence all the BSs transmit their pilot signal at the same time. Consequently, the SINR measured with respect to the pilot signal contains the worst case inter-cell interference, since the interfering signals are constantly ON during the measurement phase referring to (4),this amount to measuring the SINR with $\rho_1 = \rho_2 = 1$.

To counter the over-estimation of interfering, the CDMA-HDR system used Hybrid –ARQ.in hybride-ARQ, packet lengths, and coding and modulation schemes are chosen intelligently to allow for early packet termination. Early packet termination refer to successful reception of a packet before the normal packet duration when the channel condition is good[10].Hybrid-ARQ adjusts to network loading in the adjacent sectors, as well as to fast fading, and thereby results in a higher throughput in spite of initial conservative SINR estimates.

The benefits of the proposed scheme, and its impact on forward link scheduling and cell selection policy.

IV. A BETTER SCHEME FOR SINR ESTIMATION

Referring to fig.1,consider a terminal located in sector 0,and assume that the terminal is being served by base station 0.Assume that in addition to BS 0,the terminal has BSs 1 and 2 are in its active set of a terminal is the set of BSs whose pilot signal can be correctly decoded by the terminal. The terminal receives inter-cell interference from sectors 1 and 2.Let α_i be the forward link SINR of sector i as measured by the terminal using the current scheme[7].

Hence using (4)

$$\begin{bmatrix} \alpha_0 \\ \alpha_1 \\ \alpha_2 \end{bmatrix} = \begin{bmatrix} \frac{G_0^2 A^2 T_c}{\frac{1}{3}A^2 T_c (G_1^2+G_2^2)+2N_0} \\ \frac{G_1^2 A^2 T_c}{\frac{1}{3}A^2 T_c (G_0^2+G_2^2)+2N_0} \\ \frac{G_2^2 A^2 T_c}{\frac{1}{3}A^2 T_c (G_0^2+G_1^2)+2N_0} \end{bmatrix} \quad (5)$$

In our proposed scheme, the terminal uses the above values of α_i that are known from pilot measurements. The above set of equations are then solved to obtain channel gain G_i as follows

$$\begin{bmatrix} G_0^2 \\ G_1^2 \\ G_2^2 \end{bmatrix} = \frac{2N_0}{A^2 T_c} \begin{bmatrix} 1 & -\frac{\alpha_0}{3} & -\frac{\alpha_0}{3} \\ -\frac{\alpha_1}{3} & 1 & -\frac{\alpha_1}{3} \\ -\frac{\alpha_2}{3} & -\frac{\alpha_2}{3} & 1 \end{bmatrix}^{-1} \begin{bmatrix} \alpha_0 \\ \alpha_1 \\ \alpha_2 \end{bmatrix} \quad (6)$$

Let the actual SINR at the terminal for the forward link of sector i be β_i. This SINR takes into account the traffic load in the interfering sectors. Using (4),

$$\begin{bmatrix} \beta_0 \\ \beta_1 \\ \beta_2 \end{bmatrix} = \begin{bmatrix} \frac{G_0^2 A^2 T_c}{\frac{1}{3}A^2 T_c (G_1^2\rho_1+G_2^2\rho_2)+2N_0} \\ \frac{G_1^2 A^2 T_c}{\frac{1}{3}A^2 T_c (G_0^2\rho_0+G_2^2\rho_2)+2N_0} \\ \frac{G_2^2 A^2 T_c}{\frac{1}{3}A^2 T_c (G_0^2\rho_0+G_1^2\rho_1)+2N_0} \end{bmatrix} \quad (7)$$

Since G_i are already known from (6,the actual SINR,β_i, for each of the sectors can be obtained by using the above expressions once ρ_i are known. Thus, we do not propose alternating the current implementation of the pilot measurement procedure, and this makes our SINR estimation scheme easy to implement within the current framework.

However, we require that each base station keeps track of its forward link load ρ_i as follows. Since the derivation of (2) only requires the probability that a time slot is busy,i.e., the value of $\rho_{1,\text{the}}$ load measurement scheme is very simple. Even with multi-slot packets, the load measurement scheme only needs to know whether a time slot was empty. or busy. A long term averaging exponential filters can then be used by each BS i to determine its average load as follows.

$$\rho_i(n) = \alpha.1_{\{\text{time slot n is busy}\}}+(1-\alpha).\ \rho_i(n-1) \quad (8)$$

In the above $1_{\{.\}}$is the indicator function, and α € (0,1) is chosen to match with the frequency of load updates. if we assume that the network load dose not vary too much over an interval of 5 minutes, then the load is broadcast to the terminal once every 5 minutes and the filtering parameter is tuned appropriately. Neighboring base stations periodically exchange the information about their current forward link load so that each base station knows the load in its neighboring interfering sectors. The base station periodically broadcast this information to its users. If we assume that the traffic load over the forward link changes over the time scale of a few minutes, then the overheads of periodic load broadcasts minimal. For bursty data applications, faster load updates can be used at the cost of increased control overhead. We understand that inaccuracy in load estimation can lead to over-estimation of SINR in through proposed scheme. However, this effect can be countered by making conservative load estimates. We believe that while this is an important issue, it is an implementation detail of the scheme, and hence not the focus of this paper.

Once the terminal has the information about the network load in all the sectors that are in its active set, it can calculate the channel gains G_i using (6),and the actual SINR value β_i using(7).It is easy to see that for low values of ρ_1 and ρ_2 , the actual contribution of inter-cell interference is much less, i.e., $\beta_0 > \alpha_0$ .By using α_0 as the SINR estimate, the terminal reports a conservative data rate, and thereby gets lower throughput. Although hybrid-ARQ can dynamically cope with SINR under-estimation, we argue that a more accurate initial estimate of SINR can only improve the user throughput. The extent of improvement will be illustrated through simulation results.

We label scheme A as the scheme that uses the worst case inter-cell interference estimate, i.e., the scheme that uses α_i as the SINR estimate, and also Hybrid-ARQ for early packet termination. This scheme is used in the current standards. We label scheme B as the scheme that we propose above , the scheme that uses β_i as the SINR estimate, and also uses Hybrid-ARQ. In the next two sub-sections, we disscuse the implication of using scheme B instead of scheme A on forward link scheduling and cell selection policy.

V. INTER-CELL INTERFERENCE AND SCHEDULING

The fact that the terminals see a time-varying wireless channel over the forward link should be taken into account when scheduling data over the forward link. A class of scheduling polices called opportunistic scheduling polices have been proposed for maximizing the sector throughput by preferentially serving users with good channel condition. In all these works, as well as several other related works, no special consideration is given to the fact that the inter-cell interference has an important role to play in determining the SINR of a user. in the previous section, we saw that SINR estimation using scheme A has the disadvantage that it dose not provide an accurate estimate of the inter-cell interference contribution in the SINR. Although this dose not have an impact on the forward link opportunistic scheduling algorithm itself, it does have an impact on the outcome of the scheduling decisions. This is because under scheme A, the user located near the cell boundary report a lower data rate than the actual supportable rate. Opportunistic scheduling algorithm usually favors users that report higher supportable rate. Thus, unless the scheduling discipline takes early termination due to Hybrid-ARQ could get affected by the scheduling policy. This is because opportunistic scheduling polices base their decisions on the reported inaccurate rate estimates. Scheme B provides better user throughput to the "poor" users than Scheme A with out resulting in any degradation in the overall sector throughput.

VI. INTER-CELL INTERFERENCE AND CELL SELECTION

When a user is about to hand over to a neighboring sector using cell-selection, it measures the SINR of all the BSs in its active set to determine the best serving sector. It is possible that due to geographical nearness, the pilot-aided SINR of the terminal for BS 0 is higher than that of BS 1.i.e., $\alpha_0 > \alpha_1$. However, the actual SINR of the terminal for BS 1 may be higher than that of BS 0 i.e., $\beta_1 > \beta_0$ Thus, the user will continue to stay in sector 0 instead of handling off to sector 1.

VII. SIMULATION RESULTS

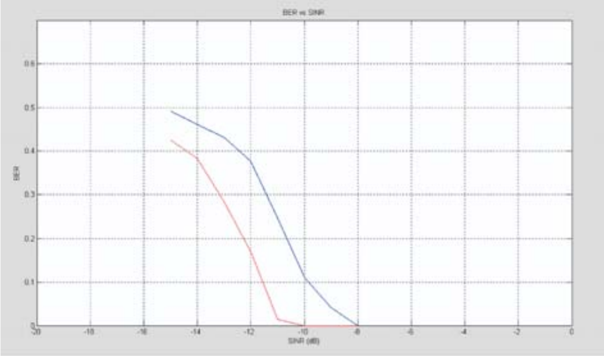

Fig. 3. BER performance at different data rates

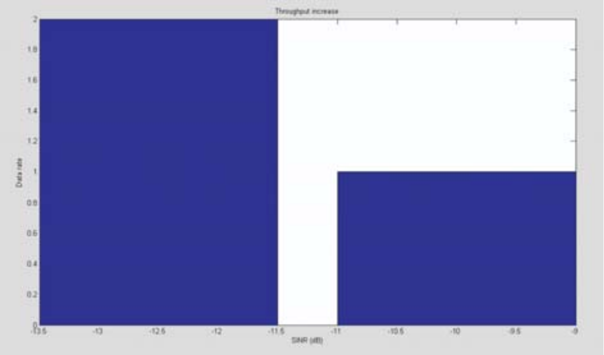

Fig. 4. Throughput increase

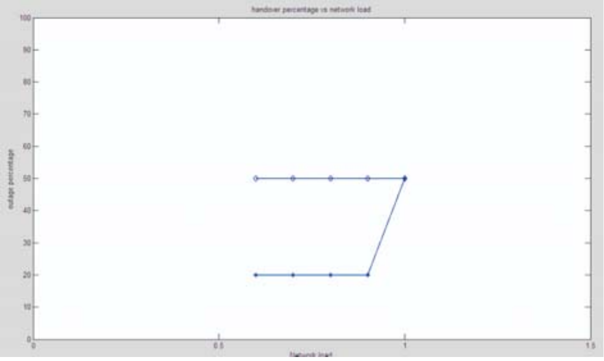

Fig. 5. Handover performance

VIII. CONCLUSION

Thus the results show that the poor users are benefited. The poor users we mean is that are most affected by the inter cell interference. These users are far away from the base station. These users will be scheduled with minimum data rate in the earlier cases without considering the network load. But by considering the network load we have the comparisons shown in the figure 4. At an interference of -10 db we have a data rate of unit 1. Whereas at an interference of -12.5 db we have data rate is doubled, and also it is transparent that the unnecessary hand over is avoided.

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