JOINT PARALLEL INTERFERENCE CANCELLATION AND RELAY SELECTION ALGORITHMS BASED ON GREEDY TECHNIQUES FOR COOPERATIVE DS-CDMA SYSTEMS

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ABSTRACT

In this work, we propose a cross-layer design strategy based on the parallel interference cancellation (PIC) detection technique and a multi-relay selection algorithm for the uplink of cooperative direct-sequence code-division multiple access (DS-CDMA) systems. We devise a low-cost greedy list-based PIC (GL-PIC) strategy with RAKE receivers as the front-end that can approach the maximum likelihood detector performance. We also present a low-complexity multi-relay selection algorithm based on greedy techniques that can approach the performance of an exhaustive search. Simulations show an excellent bit error rate performance of the proposed detection and relay selection algorithms as compared to existing techniques.

Index Terms— DS-CDMA networks, cooperative systems, relay selection, greedy algorithms, PIC detection.

1. INTRODUCTION

Multipath fading is a major constraint that seriously limits the performance of wireless communications. Indeed, severe fading has a detrimental effect on the received signals and can lead to a degradation of the transmission of information and the reliability of the network. Cooperative diversity is a modern technique that has been widely considered in recent years [1] as an effective tool to deal with this problem. Several cooperative schemes have been proposed in the literature [2, 3, 4], and among the most effective ones are Amplify–and–Forward (AF) and Decode–and–Forward (DF) [4].

DS-CDMA systems are a multiple access technique that can be incorporated with cooperative systems in ad hoc and sensor networks [5, 6, 7]. Due to the multiple access interference (MAI) effect that arises from nonorthogonal received waveforms, the system is adversely affected. To deal with this issue, multiuser detection (MUD) techniques have been developed [8] as an effective approach to suppress MAI. The optimal detector, known as maximum likelihood (ML) detector, has been proposed in [9]. However, this method is infeasible for ad hoc and sensor networks considering its computational complexity. Motivated by this fact, several sub-optimal strategies have been developed: the linear detector [10], the successive interference cancellation (SIC) [11], the parallel interference cancellation (PIC) [12] and the minimum mean-square error (MMSE) decision feedback detector [13].

In cooperative relaying systems, different strategies that utilize multiple relays have been recently introduced in [14, 15, 16, 17, 18]. Among these approaches, a greedy algorithm is an effective way to approach the global optimal solution. Greedy algorithms have been widely applied in sparse approximation [19], internet routing [20] and arithmetic coding [21]. In relay assisted systems, greedy algorithms are used in [16, 17] to search for the best relay combination, however, with insufficient numbers of combinations considered, a significant performance loss is experienced as compared to an exhaustive search.

The aim of this work is to propose a cross-layer approach that jointly considers the optimization of a low-complexity detection and a relay selection algorithm for ad hoc and sensor networks that employ DS-CDMA systems. Cross-layer designs that integrate different layers of the network have been employed in prior work [22, 23] to guarantee the quality of service and help increase the capacity, reliability and coverage of systems. However, involving MUD techniques with relay selection in cooperative relaying systems has not been discussed widely in the literature. In [3, 24], an MMSE-MUD technique has been applied to the cooperative systems, the results indicate that the transmissions are more resistant to MAI and obtain a significant performance gain when compared with a single direct transmission. However, extra complexity is introduced, as matrix inversions are required when an MMSE filter is deployed.

In this work, we devise a low-cost greedy list-based parallel interference cancellation (GL-PIC) strategy with RAKE receivers as the front-end that can approach the maximum likelihood detector performance. Unlike prior art, the proposed GL-PIC algorithm exploits the Euclidean distance between users of interest and the nearest constellation points, re-examines the reliability of the estimates so that all possible combination lists of tentative decisions can be checked. With this greedy-like approach, an improved detection performance can be obtained. We also present a low-complexity multi-relay selection algorithm based on greedy techniques that can approach the performance of an exhaustive search. In the proposed greedy algorithm, a selection rule is employed via several stages. At each stage, a limited number of relay combinations is examined and compared, resulting in a low-cost strategy to approach the performance of an exhaustive search. A cross-layer design strategy that brings together the proposed GL-PIC algorithm and the greedy relay selection is then considered and evaluated by computer simulations.

The rest of this paper is organized as follows. In Section 2, the system model is described. In Section 3, the GL-PIC multiuser detection method is presented. In Section 4, the relay selection strategy is proposed. In Section 5, simulation results are presented and discussed. Finally, conclusions are drawn in Section 6.

2. COOPERATIVE DS-CDMA SYSTEM MODEL

We consider the uplink of a synchronous DS-CDMA system with K users $(k_1, k_2, ...k_K)$, L relays $(l_1, l_2, ...l_L)$, N chips per symbol and L_p $(L_p < N)$ propagation paths for each link. The system is equipped with a DF protocol at each relay and we assume that the

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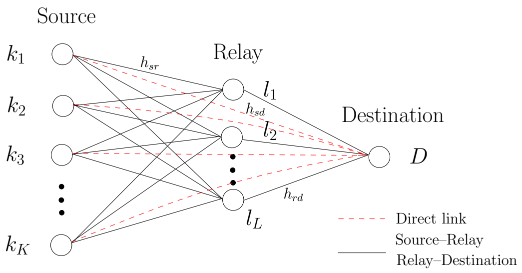

Fig. 1. Uplink of a cooperative DS-CDMA system.

transmit data are organized in packets comprising P symbols. The received signals are filtered by a matched filter, sampled at chip rate to obtain sufficient statistics and organized into $M \times 1$ vectors $\mathbf{y}_{sd}$, $\mathbf{y}_{sr}$ and $\mathbf{y}_{rd}$, which represent the signals received from the sources (users) to the destination, the sources to the relays and the relays to the destination, respectively. The proposed algorithms for interference mitigation and relay selection are employed at the relays and at the destination. As shown in Fig.1, the received signal at the destination comprises the data transmitted during two phases that are jointly processed at the destination. Therefore, the received signal is described by a $2M \times 1$ vector formed by stacking the received signals from the relays and the sources as given by

$$\begin{bmatrix} \mathbf{y}_{sd} \\ \mathbf{y}_{rd} \end{bmatrix} = \begin{bmatrix} \sum\limits_{k=1}^{K} a_{sd}^{k} \mathbf{S}_k \mathbf{h}_{sd,k} b_k \\ \sum\limits_{l=1}^{L} \sum\limits_{k=1}^{K} a_{r_l d}^{k} \mathbf{S}_k \mathbf{h}_{r_l d,k} \hat{b}_{r_l d,k} \end{bmatrix} + \begin{bmatrix} \mathbf{n}_{sd} \\ \mathbf{n}_{rd} \end{bmatrix}, \quad (1)$$

where $M = N + L_p - 1$, $b_k \in \{+1, -1\}$ correspond to the transmitted symbols, a_{sd}^{k} and $a_{r_l d}^{k}$ represent the k-th user's amplitude from the source to the destination and from the l-th relay to the destination. The $M \times L_p$ matrix $\mathbf{S}_k$ contains the signature sequence of each user shifted down by one position at each column that forms

$$\mathbf{S}_k = \begin{bmatrix} s_k(1) & & \mathbf{0} \\ \vdots & \ddots & s_k(1) \\ s_k(N) & & \vdots \\ \mathbf{0} & \ddots & s_k(N) \end{bmatrix}, \quad (2)$$

where $\mathbf{s}_k = [s_k(1), s_k(2), ...s_k(N)]^T$ is the signature sequence for user k. The vectors $\mathbf{h}_{sd,k}$, $\mathbf{h}_{r_l d,k}$ are the $L_p \times 1$ channel vectors for user k from the source to the destination and the l-th relay to the destination. The $M \times 1$ noise vectors $\mathbf{n}_{sd}$ and $\mathbf{n}_{rd}$ contain samples of zero mean complex Gaussian noise with variance σ^2, $\hat{b}_{r_l d,k}$ is the decoded symbol at the output of relay l after using the DF protocol. The received signal in (1) can then be described by

$$\mathbf{y}_d(i) = \sum_{k=1}^{K} \mathbf{C}_k \mathbf{H}_k(i) \mathbf{A}_k(i) \mathbf{B}_k(i) + \mathbf{n}(i), \quad (3)$$

where i denotes the time instant corresponding to one symbol in the transmitted packet and its received and relayed copies. $\mathbf{C}_k$ is a $2M \times (L+1)L_p$ matrix comprising shifted versions of $\mathbf{S}_k$ as given by

$$\mathbf{C}_k = \begin{bmatrix} \mathbf{S}_k & \mathbf{0} & \dots & \mathbf{0} \\ \mathbf{0} & \mathbf{S}_k & \dots & \mathbf{S}_k \end{bmatrix}, \quad (4)$$

$\mathbf{H}_k(i)$ represents a $(L+1)L_p \times (L+1)$ channel matrix between the sources and the destination and the relays and the destination links. $\mathbf{A}_k(i)$ is a $(L+1) \times (L+1)$ diagonal matrix of amplitudes for user k. The matrix $\mathbf{B}_k(i) = [b_k, \hat{b}_{r_1 d,k}, \hat{b}_{r_2 d,k}, ...\hat{b}_{r_L d,k}]^T$ is a $(L+1) \times 1$ vector for user k that contains the transmitted symbol at the source and the detected symbols at the output of each relay, and $\mathbf{n}(i)$ is a $2M \times 1$ noise vector.

3. THE PROPOSED GL-PIC MULTIUSER DETECTOR

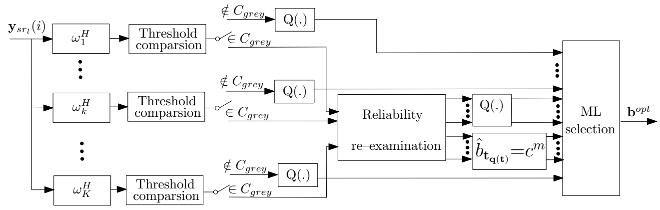

Fig. 2. Block diagram of the proposed GL-PIC multi-user detector.

In this section, we present a GL-PIC detector that can be applied at both the relays and destination in the uplink of a cooperative system. The GL-PIC detector uses the RAKE receiver as the front-end, so that the matrix inversion brought by the MMSE filter can be avoided. With the structure depicted in Fig.2, the proposed GL-PIC algorithm determines the reliability of the detected symbol by comparing the Euclidean distance between the symbol of users of interest and the potential nearest constellation point with a chosen threshold. After checking the reliability of the symbol estimates by listing all possible combinations of tentative decisions, the n_q most unreliable users are re-examined via a number of selected constellation points in a greedy-like approach, which saves computational complexity by avoiding redundant processing with reliable users. Following the diagram in Fig.2, the soft estimates of the RAKE receiver for each user are obtained by

$$u_k(i) = \mathbf{w}_k^H \mathbf{y}_{sr_l}(i), \quad (5)$$

where $\mathbf{y}_{sr_l}(i)$ represents the received signal from the source to the l-th relay, $u_k(i)$ stands for the soft output of the i-th symbol for user k and $\mathbf{w}_k$ denotes the RAKE receiver that corresponds to a filter matched to the effective signature at the receiver. As shown by Fig.3, β is the distance between two nearest constellation points, d_{th} is the threshold. For the k-th user, the reliability of its soft estimates is determined by the Euclidean distance between $u_k(i)$ and its nearest constellation points c.

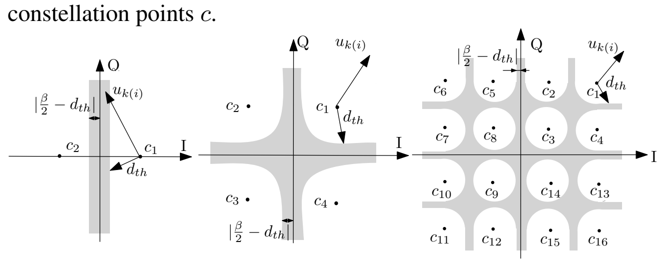

Fig. 3. The reliability check for soft estimates in BPSK, QPSK and 16 QAM constellations.

Decision reliable:

If the soft estimates of n_a users satisfy the following condition

$$u_{\mathbf{t}_a(t)}(i) \notin \mathbf{C}_{\text{grey}}, \quad \text{for } t \in [1, 2, ..., n_a], \quad (6)$$

where $\mathbf{t}_a$ is a $1 \times n_a$ vector that contains n_a reliable estimates, $\mathbf{C}_{\text{grey}}$ is the grey area in Fig.3 and the grey area would extend along both the vertical and horizontal directions. These soft estimates will be applied to a slicer $Q(\cdot)$ as described by

$$\hat{b}_{\mathbf{t}_a(t)}(i) = Q(u_{\mathbf{t}_a(t)}(i)), \text{ for } t \in [1, 2, ..., n_a], \quad (7)$$

where $\hat{b}_{\mathbf{t}_a(t)}(i)$ denotes the detected symbol for the $\mathbf{t}_a(t)$-th user.

Decision unreliable:

In case that n_b users are determined as unreliable, a $1 \times n_b$ vector $\mathbf{t}_b$ with n_b unreliable estimates included is produced, as given by

$$u_{\mathbf{t}_b(t)}(i) \in \mathbf{C}_{\text{grey}}, \quad \text{for } t \in [1, 2, ..., n_b], \quad (8)$$

we then sort these unreliable estimates in terms of their Euclidean distance in a descending order. Consequently, the first n_q users from the ordered set are deemed as the most unreliable ones as they experience the farthest distance to their reference constellation points. These n_q estimates are then examined in terms of all possible constellation values c^m $(m = 1, 2, ..., N_c)$ from the $1 \times N_c$ constellation points set $\mathbf{C} \subseteq F$, where F is a subset of the complex field, and N_c is determined by the modulation type. Meanwhile, the remaining $n_p = n_b - n_q$ unreliable users are applied to the slicer $Q(\cdot)$ directly, as described by

$$\hat{b}_{\mathbf{t}_p(t)}(i) = Q(u_{\mathbf{t}_p(t)}(i)), \text{ for } t \in [1, 2, ..., n_p], \tag{9}$$

$$\hat{b}_{\mathbf{t}_q(t)}(i) = c^m, \text{ for } t \in [1, 2, ..., n_q], \tag{10}$$

where $\mathbf{t}_p \cap \mathbf{t}_q = \varnothing$ and $\mathbf{t}_p \cup \mathbf{t}_q = \mathbf{t}_b$. Therefore, by listing all possible combinations of elements across the n_q most unreliable users, the following $K \times 1$ tentative candidate decision lists are generated

$$\mathbf{b}^j = [\mathbf{s}_a, \ \mathbf{s}_p, \ \mathbf{s}_q^j]^T, \ j = 1, 2, ..., N_c^{n_q}, \tag{11}$$

where $\mathbf{s}_a = [\hat{b}_{\mathbf{t}_a(1)}, \hat{b}_{\mathbf{t}_a(2)}, ..., \hat{b}_{\mathbf{t}_a(n_a)}]^T$ is a $n_a \times 1$ vector that contains the detected values for the n_a reliable users, $\mathbf{s}_p = [\hat{b}_{\mathbf{t}_p(1)}, \hat{b}_{\mathbf{t}_p(2)}, ..., \hat{b}_{\mathbf{t}_p(n_p)}]^T$ is a $n_p \times 1$ vector that represents n_p unreliable users that are detected by the slicer $Q(\cdot)$ directly, and $\mathbf{s}_q^j = [c^m_{\mathbf{t}_q(1)}, c^m_{\mathbf{t}_q(2)}, ..., c^m_{\mathbf{t}_q(n_q)}]^T$ is a $n_q \times 1$ tentative candidate combination vector. Each entry of the vector is selected randomly from the constellation point set $\mathbf{C}$ and all possible $N_c^{n_q}$ combinations need to be considered and examined. The trade-off between performance and complexity is highly related to the modulation type and the number (n_q) of users we choose from $\mathbf{t}_b$. Additionally, the threshold we set at the initial stage is also a key factor that could affect the quality of detection.

After the $N_c^{n_q}$ candidate lists are generated, the ML rule is used subsequently to choose the best candidate list as described by

$$\mathbf{b}^{\text{opt}} = \min_{1 \leq j \leq N_c^{n_q}} \parallel \mathbf{y}_{sr_l}(i) - \mathbf{H}_{sr_l}\mathbf{b}^j(i) \parallel^2 . \tag{12}$$

Following that, $\mathbf{b}^{\text{opt}}$ is used as the input for a multi-iteration PIC process as described by

$$\hat{b}_k^i = Q(\mathbf{H}^H_{sr_l,k}\mathbf{y}_{sr_l} - \sum_{\substack{j=1 \\ j \neq k}}^{K} \mathbf{H}^H_{sr_l,k}\mathbf{H}_{sr_l,j}\hat{b}_j^{i-1}), \tag{13}$$

where $\hat{b}_k^i$ denotes the detected value for user k at the i-th PIC iteration, $\mathbf{H}_{sr_l,k}$ and $\mathbf{H}_{sr_l,j}$ stand for the channel matrices for the k-th and j-th user from the source to the l-th relay, respectively. $\hat{b}_j^{i-1}$ is the detected value for user j that comes from the $(i-1)$-th PIC iteration. Normally, the conventional PIC is performed in a multi-iteration way, where for each iteration, PIC simultaneously subtracts off the interference for each user produced by the remaining ones. The MAI generated by other users is reconstructed based on the tentative decisions from the previous iteration. Therefore, the accuracy of the first iteration would highly affect the PIC performance as error propagation occurs when incorrect information imports. In this case, with the help of the GL-PIC algorithm, we are able to improve the accuracy of the detection and obtain a better performance.

4. PROPOSED GREEDY MULTI-RELAY SELECTION METHOD

In this section, a greedy multi-relay selection method is introduced. For this problem, an exhaustive search of all possible subsets of relays is needed to attain the optimum relay combination. However, an exhaustive search presents a considerable computational complexity, limiting its application in practical systems. With L relays involved in the transmission, an exponential complexity of $2^L - 1$ would be required. This fact motivates us to seek other alternative methods. By mitigating the poorest relay-destination link stage by stage, the standard greedy algorithm can be used in the selection process, yet only a local optimum can be achieved. Unlike the traditional ways, the proposed greedy multi-relay selection method can go through a sufficient number of relay combinations and approach the best one based on previous decisions. In the proposed relay selection, the signal to interference and noise ratio (SINR) is used as the criterion to determine the optimum relay set. The expression of the SINR is expressed by

$$\mathrm{SINR_q} = \frac{E[|\mathbf{w}_q^H\mathbf{r}|^2]}{E[|\boldsymbol{\eta}|^2] + n}, \tag{14}$$

where $\mathbf{w}_q$ denotes the RAKE receiver for user q, $E[|\boldsymbol{\eta}|^2] = E[|\sum_{\substack{k=1 \\ k \neq q}}^{K} \mathbf{H}_k b_k|^2]$ is the interference brought by all other users, and n is the noise. For the RAKE receiver, the SINR is given by

$$\mathrm{SINR_q} = \frac{\mathbf{h}_q^H\mathbf{H}\mathbf{H}^H\mathbf{h}_q}{\text{trace}(\mathbf{H}_\eta\mathbf{H}_\eta^H) + \mathbf{h}_q^H\sigma_N^2\mathbf{h}_q}, \tag{15}$$

where $\mathbf{h}_q$ is the channel vector for user q, $\mathbf{H}$ is the channel matrix for all users, $\mathbf{H}_\eta$ represents the channel matrix of all other users except user q. It should be mentioned that in various relay combinations, the channel vector $\mathbf{h}_q$ for user q $(q = 1, 2, ..., K)$ is different as different relay-destination links are involved, σ_N^2 is the noise variance. This problem thus can be cast as the following optimization:

$$\mathrm{SINR}_{\Omega_{\text{best}}} = \max \ \{\min(\mathrm{SINR}_{\Omega_{\mathrm{r(q)}}}), \mathrm{q} = 1, ..., \mathrm{K}\}, \tag{16}$$

where Ω_r denotes all possible combination sets $(r \leq L(L+1)/2)$ of any number of selected relays, $\mathrm{SINR}_{\Omega_{\mathrm{r(q)}}}$ represents the SINR for user q in set Ω_r, min $(\mathrm{SINR}_{\Omega_{\mathrm{r(q)}}}) = \mathrm{SINR}_{\Omega_\mathrm{r}}$ stands for the SINR for relay set Ω_r and Ω_{best} is the best relay set that provides the highest SINR.

4.1. Standard greedy relay selection algorithm

The standard greedy relay selection method works in stages by removing the single relay according to the channel path power, as given by

$$P_{h_{r_ld}} = \mathbf{h}_{r_ld}^H\mathbf{h}_{r_ld}, \tag{17}$$

where $\mathbf{h}_{r_ld}$ is the channel vector between the l-th relay and the destination. At the first stage, the initial SINR is determined when all L relays are involved in the transmission. Consequently, we cancel the worst relay-destination link and calculate the current SINR for the remaining $L-1$ relays, as compared with the previous SINR, if

$$\mathrm{SINR_{cur}} > \mathrm{SINR_{pre}}, \tag{18}$$

we update the previous SINR as

$$\mathrm{SINR_{pre}} = \mathrm{SINR_{cur}}, \tag{19}$$

and move to the third stage by removing the current poorest link and repeating the above process. The algorithm stops either when $\mathrm{SINR_{cur}} < \mathrm{SINR_{pre}}$ or when there is only one relay left. The selection is performed once at the beginning of each packet transmission.

4.2. Proposed greedy relay selection algorithm

In order to improve the performance of the standard algorithm, we propose a new greedy relay selection algorithm that is able to achieve a good balance between the performance and the complexity. The proposed method differs from the standard technique as we drop each of the relays in turns rather than drop them based on the channel condition at each stage. The algorithm can be summarized as:

1. Initially, a set Ω_A that includes all L relays is generated and its corresponding SINR is calculated, denoted by $\mathrm{SINR_{pre}}$.
2. For the second stage, we calculate the SINR for L combination sets with each dropping one of the relays from Ω_A. After that, we pick the combination set with the highest SINR for this stage, recorded as $\mathrm{SINR_{cur}}$.
3. Compare $\mathrm{SINR_{cur}}$ with the previous stage $\mathrm{SINR_{pre}}$, if (18) is true, we save this corresponding relay combination as Ω_{cur} at this stage. Meanwhile, we update the $\mathrm{SINR_{pre}}$ as in (19).

4. After moving to the third stage, we drop relays in turn again from Ω_{cur} obtained in stage two. $L-1$ new combination sets are generated, we then select the set with the highest SINR and repeat the above process in the following stages until either $\text{SINR}_{\text{cur}} < \text{SINR}_{\text{pre}}$ or there is only one relay left.

This new greedy selection method considers the combination effect of the channel condition so that additional useful sets are examined. When compared with the standard greedy relay selection method, the previous stage decision is more accurate and the global optimum can be approached more closely. Furthermore, its complexity is less than $L(L+1)/2$, which is much lower than the exhaustive search. Similarly, the whole process is performed only once before each packet.

Table 1. The proposed greedy multi-relay selection algorithm

$\Omega_A = [1, 2, 3, ...L]$% Ω_A denotes the set when all relays are involved
$\text{SINR}_{\Omega_A} = \min(\text{SINR}_{\Omega_{A(q)}}), q = 1, 2, ...K$
$\text{SINR}_{\text{pre}} = \text{SINR}_{\Omega_A}$
for stage =1 **to** $L-1$
  for r=1 **to** $L+1$-stage
    $\Omega_r = \Omega_A - \Omega_{A(r)}$% drop each of the relays in turns
    $\text{SINR}_{\Omega_r} = \min(\text{SINR}_{\Omega_{r(q)}}), q = 1, 2, ..., K$
  end for
  $\text{SINR}_{\text{cur}} = \max(\text{SINR}_{\Omega_r})$
  $\Omega_{\text{cur}} = \Omega_{\text{SINR}_{\text{cur}}}$
  if $\text{SINR}_{\text{cur}} > \text{SINR}_{\text{pre}}$ **and** $\text{length}(\Omega_{\text{cur}}) > 1$
    $\Omega_A = \Omega_{\text{cur}}$
    $\text{SINR}_{\text{pre}} = \text{SINR}_{\text{cur}}$
  else
    break
  end if
end for

5. SIMULATIONS

In this section, a simulation study of the proposed GL-PIC multiuser detection strategy with a RAKE receiver and the low cost greedy multi-relay selection method is carried out. The DS-CDMA network uses randomly generated spreading codes of length $N = 16$ and employs $L_p = 3$ independent paths with the power profile $[0\text{dB}, -3\text{dB}, -6\text{dB}]$ for each source-relay, source-destination and relay-destination link. Their corresponding channel coefficients are taken as uniformly random variables and normalized to ensure the total power is unity. We assume perfectly known channels at the receiver. Equal power allocation with normalization is assumed to guarantee no extra power is introduced during the transmission. The grey area in the GL-SIC algorithm is determined by the threshold where $d_{th} = 0.25$. We consider packets with 1000 BPSK symbols and average the curves over 300 trials. For the purpose of simplicity, in the GL-PIC algorithm, a three-iteration PIC process is adopted and BPSK modulation technique is applied in the simulations.

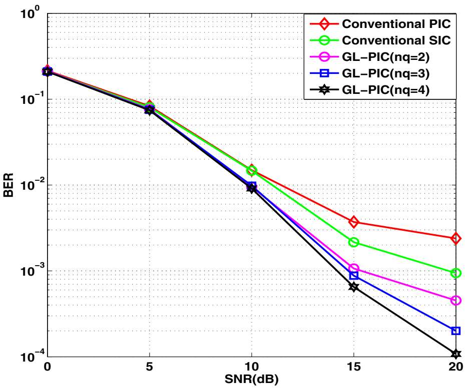

Fig. 4. BER versus SNR for uplink cooperative system with different filters employed in the relays and the destination

The first example, shown in Fig.4 depicts the performance for the proposed cross-layer design, where we compare the effect of different detectors with 10 users and 6 relays when the proposed greedy multi-relay selection algorithm is applied in the system. Simulation results indicate that the GL-PIC approach allows a more effective reduction of BER, followed by the conventional SIC detector and the conventional PIC detector. Additionally, it is worth noting that some extra performance gains are attained as more n_q unreliable users are selected and re-examined.

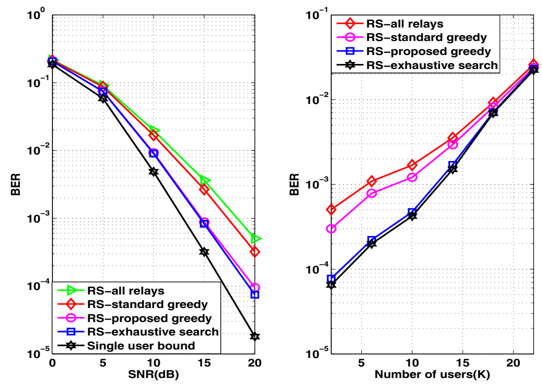

Fig. 5. a) BER versus SNR for uplink cooperative system b) BER versus number of users for uplink cooperative system

The second scenario illustrated in Fig.5(a) shows the BER versus SNR plot for employing different multi-relay selection strategies, where we apply the GL-PIC detection scheme at both the relays and destination in an uplink cooperative scenario with 10 users and 6 relays. The performance bound for an exhaustive search is presented here for comparison purposes, where it examines all possible relay combinations and picks the one with the highest SINR. From the results, it can be seen that with relay selection, the BER performance substantially improves. Furthermore, the BER performance curve of our proposed multi-relay selection algorithm outperforms the standard greedy algorithm and approaches the same level of the exhaustive search, whilst keeping the complexity reasonably low for practical utilization.

The algorithms are then assessed in terms of the BER versus number of users in Fig.5(b) with a fixed SNR=15dB. Similarly, we apply the GL-PIC detector at both the relays and destination. The results indicate that the overall system performance degrades as the number of users increases. It also suggests that our proposed greedy relay selection method has a big advantage for situations without a high load when compared with the standard greedy relay selection and a scenario without relay selection.

6. CONCLUSIONS

A novel cross-layer design strategy that incorporates the greedy list-based parallel interference cancellation (GL-PIC) detection technique and a low cost greedy multi-relay selection algorithm for the uplink of cooperative DS-CDMA systems has been presented in this paper. This approach effectively mitigates the phenomenon of error propagation and selects the optimum relay combination while requiring a low complexity. Simulation results demonstrate that the proposed cross-layer optimization technique can offer considerable gains as compared to existing detectors and can approach the exhaustive search bound very closely.

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