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An Efficient Partner Selection Method to Overcome the Interference Effect in Wireless Networks

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ABSTRACT In this paper, through a mathematical analysis of the overall links capacity equation, we present an efficient partner selection criterion in a cooperative communication scheme with a time-varying fading channel and severe interference on the cooperative links to mitigate the interference effect without the need for additional power consumption to transmit the information signal. For the partner(s) selection, we examine different selection criteria based on minimizing the error rate and maximizing the end-to-end system capacity to collaborate in the delivery process. We prove that in the proposed relay scheme, a simple selection criterion independent of the interference state is a sufficient and efficient criterion for selecting the partners out of terminals suffering from interference. It is found that the use of a simple and efficient selection criterion for assigning multiple cooperating terminals is able to achieve a significant diversity gain, conserve the energy of individual terminals, and improve the error performance with low computational complexity, even in the absence of the interference state information. All of the theoretical findings are verified through simulation studies.

INDEX TERMS Amplify and forward, cooperative communication, decode and forward, diversity gain, system capacity.

I. INTRODUCTION

Cooperative diversity has been recognized as a promising way to provide a spatial degree of freedom to single-antenna systems by exploiting the space diversity of distributed users acting as relays. Cooperating users with a good channel state overhear the broadcast transmission and forward a processed version of it to the destination. Several strategies, such as Amplify-and-Forward (AF) and Decode-and-Forward (DF), can be employed by the cooperating user(s) to provide the powerful benefits of the spatial diversity of the distributed antennas without the need for physical arrays, especially when space constraints preclude their use. For instance physical implementation of multiple antennas at a small node may not be realistic [1]. Between these two strategies, AF, which operates by simply multiplying the received signal by a fixed or channel-state information (CSI)-dependent amplification factor, has lower computational complexity. To achieve cooperative communication, it is important to determine who and how many partners are necessary to record an improvement in performance. Several selection schemes that improve performance by minimizing the error rate [2], minimizing the transmission time [3], maximizing the capacity [4], [5] or minimizing the outage probability [6] have been studied by the research community. Relay selection can be based on the distance of the node to the source or destination [7]. Energy efficiency is considered in [8], which aims to select a relay to minimize the power consumption of the system. Some research efforts have formulated relay selection as an optimization problem to optimally allocate the resources to the selected node [9]–[11]. For example, in [9], single and multi-objective relay selection problems are formulated to make a single relay selection and set a transmission link in addition to the direct link between the source and the destination. The proposed optimization problem is compared with an exhaustive search that needs to test all possible solutions with intolerable computational complexity.

Although a single relay selection in the AF cooperation scheme has been well studied in the literature using different selection criteria, most of the existing work assumes interference-free transmission [12]–[14]. For example, [13] selects a relay that maximizes the harmonic mean of the

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end-to-end (i.e., source-to-relay and relay-to-destination) channel gain. In this paper, relay and partner are used interchangeably.

However, a simple three-node topology does not represent the reality of multiple concurrent transmissions. The max-min criterion is applied in [15] for the selection of a single partner in the AF scheme with the presence of interference. On the other hand, selection criteria that consider interference channel information create additional overhead and computational complexity [16]–[21]. A simpler and easier-to-implement selection criterion is used in [20]; with an interference impact on the candidate relays, a single relay with the highest signal-to-interference-and-noise ratio (SINR) is selected. Multiple relays are selected based on the same criterion proposed in [22]. However, the criterion depends only on the channel quality in the first transmission phase between the source and the relays. The results of the current work demonstrate an outstanding gain in performance if the quality of the second transmission is also considered in the selection process.

In this work, different criteria are applied to select a number of cooperating terminals for the development of diverse transmission links. The goal is to leverage the utilization of a network through a simple and easy-to-implement cooperation framework. Most previous works assume an interference-free environment, while others claim the necessity of a complex selection process that considers the interference state information. In this work, we demonstrate the efficacy of a selection criterion that is independent of the interference state information. The results show that a gain is achieved by involving more than a single cooperating terminal in the cooperation process. A time-varying Rayleigh fading channel with a co-channel interference effect in the cooperative links is considered. The selection adapts to the channel state information between the terminals and records any improvements in terms of error performance, user energy savings and transmission rate. A simple procedure with a low-overhead process is necessary to make a decision prior to the channel state update. The schemes are applicable to any wireless setting, including cellular or ad hoc networks at any location.

The paper is organized in four sections. Section II presents a theoretical analysis, describes the system model and discusses the criteria used to select the relay(s) from the available terminals. A simulation study is presented in Section III, and the work is concluded in Section IV.

II. SYSTEM MODEL

Consider a simple ad hoc configuration based on the cooperative concept; the configuration has one source, one destination, and a set of R terminals that are able to cooperate if required, as depicted in Figure 1. It is assumed that a direct link between the source and the destination is not available and that all the nodes are half-duplex. Communication is achieved by two orthogonal channels, i.e., two transmission phases. In the first phase, the source broadcasts a message, and the surrounding nodes listen. The selection policy based on CSI is applied. A distributed or centralized controller that has all CSI can make decisions to choose a candidate set of partners to forward the delivered signal in the second phase. The selection process is updated when there is a significant change in the channel quality. The cooperating partners either amplify or decode and re-encode the received signal before retransmitting it to the destination. Because AF is more commonly used in many real-time applications [23]–[25], an AF relay network is first considered; later, the modifications that would be necessary when a DF relay network is introduced are described.

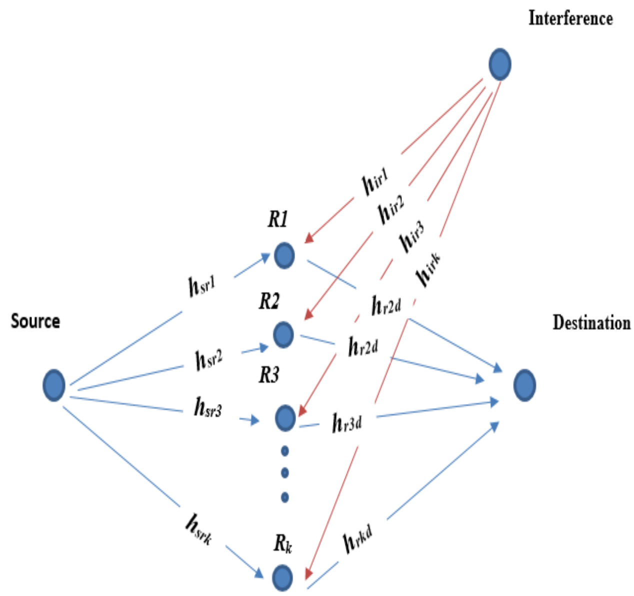

FIGURE 1. System model of a wireless relay network.

A. AF RELAY SCHEME

Interference can disturb the transmission in both phases; however, an additional link is initially assumed to interfere with each transmission in the first phase only. Assuming the interference signal is deeply degraded at the destination because of the distance, shadowing or pathless. The cooperating partners are unable to differentiate between the signal of interest and the interference signal, and they simply amplify the resultant signal based on the total received power. Coherent detection with channel state information of the transmitting links is applied at the destination.

The system in Figure 1 consists of a source, a destination and a set of surrounding terminals that are willing to cooperate. The main system model parameters are listed in Table 1. In the case of single partner selection (r_k), the received signal at the partner y_r and the intended destination y_d are given by the following equations:

$$y_r = \sqrt{P_s} h_{sr} x + \sqrt{P_I} h_{Ir} I + \eta_{sr} \tag{1}$$

$$y_d = \beta_r \sqrt{P_r} h_{rd} y_r + \eta_{rd} \tag{2}$$

The source broadcasts x with a transmission power P_s. I is an interference signal sent with a power P_I that overlaps

TABLE 1. System model parameters.

Symbol	Quantity
x	Transmitted signal
I	Interference signal
P_s, P_r, P_I	Source, relay and interference power, respectively
h_{sr}, h_{rd}, h_{Ir}	Source-relay, relay-destination and interference-relay channel coefficients, respectively
β_r	Amplification factor of a relay
${\sigma_{sr}}^2, {\sigma_{rd}}^2$	Source-relay and relay destination noise power, respectively

with the delivered signal in the first transmission phase. The total consumed power required to transmit a signal is the sum of P_s and P_r. h_{sr}, h_{rd} and h_{Ir} represent the channels of the transmission links shown in Figure 1. The channels are modeled as zero-mean independent complex Gaussian random variables. η_{sr} and η_{rd} denote the additive Gaussian random variables of the two transmission links.

A candidate partner would amplify the received signal with an amplification factor β_r and retransmit it at a power level P_r. To ensure that the average power of the partner signal $E\left[x_{rk}^2\right]$ satisfies the power constraint,

$$E\left[x_{rk}^2\right] = \beta_r^2\{P_s\,|h_{sr}|^2 + P_I\,|h_{Ir}|^2 + \sigma_{sr}^2\} \leq 1, \tag{3}$$

and the amplification factor β_r for each cooperating relay is given as [12], [20]

$$\beta_r = \sqrt{\frac{1}{P_s|h_{sr}|^2 + P_I|h_{Ir}|^2 + \sigma_{sr}^2}} \tag{4}$$

σ_{sr}^2 and σ_{rd}^2 are the source-relay and relay-destination channel noise powers, respectively. The capacity of the first and second transmission time slots is given by

$$C_1 = \log_2\left(1 + \frac{P_s\,|h_{sr}|^2}{P_I\,|h_{Ir}|^2 + \sigma_{sr}^2}\right) \tag{5}$$

$$C_2 = \log_2(1 + \zeta_r) \tag{6}$$

At each cooperating relay,

$$\zeta_r = \frac{P_s\,|h_{sr}|^2\,|h_{rd}|^2\,\beta_r^2}{P_I\,|h_{rd}|^2\,|h_{Ir}|^2\,\beta_r^2 + |h_{rd}|^2\,\beta_r^2\sigma_{sr}^2 + \partial_r} \tag{7}$$

and

$$\partial_r = \sigma_{rd}^2/P_r \tag{8}$$

The sum capacity of two transmission phases, C,is given by

$$C = \frac{1}{2}(C_1 + C_2) \tag{9}$$

The sum of the two capacity terms is divided by two because two time slots are required to communicate between the source and the destination. Therefore, the sum capacity can be expressed as follows:

$$C = \frac{1}{2}\log_2[(1 + \frac{P_s\,|h_{sr}|^2}{P_I\,|h_{Ir}|^2 + \sigma_{sr}^2})(1 + \zeta_r)] \tag{10}$$

In the interference-free environment, $P_I = 0$; thus, the second term in the denominator of (4) will vanish, and

$$\zeta_r = \frac{|h_{sr}|^2\,|h_{rd}|^2\,\beta_r^2}{|h_{rd}|^2\,\beta_r^2\sigma_{sr}^2 + \partial_r} \tag{11}$$

Therefore,

$$C = \frac{1}{2}\log_2[1 + \zeta_r + \frac{|h_{sr}|^2}{\vartheta_r} + \frac{\zeta_r\,|h_{sr}|^2}{\vartheta_r}] \tag{12}$$

and

$$\vartheta_r = \sigma_{sr}^2/P_s \tag{13}$$

Different criteria can be used to leverage system utilization. To highlight the possible criterion in the selection process, one could attempt to maximize the logarithmic term or minimize its inverse. By considering the terms inside the brackets individually and instituting the amplification gain as given in (4), these equivalencies can be identified.

$$\max_{r\,\in\,R}\,[\zeta_r] \equiv \min_{r\,\in\,R}\,[\frac{\vartheta_r}{|h_{sr}|^2} + \frac{\partial_r}{|h_{rd}|^2} + \frac{\vartheta_r\partial_r}{|h_{sr}|^2\,|h_{rd}|^2}]$$

$$\max_{r\,\in\,R}\left[\frac{|h_{sr}|^2}{\vartheta_r}\right] \equiv \min_{r\,\in\,R}\left[\frac{\vartheta_r}{|h_{sr}|^2}\right]$$

$$\max_{r\,\in\,R}[\frac{\zeta_r\,|h_{sr}|^2}{\vartheta_r}] \equiv \min_{r\,\in\,R}\,[\frac{\vartheta_r^2}{|h_{sr}|^4} + \frac{\vartheta_r\partial_r}{|h_{sr}|^2\,|h_{rd}|^2} + \frac{\vartheta_r^2\partial_r}{|h_{sr}|^4\,|h_{rd}|^2}]$$

R represents a set of surrounding terminals that are willing to cooperate and work as relays. It is clear that the network utilization can be leveraged by minimizing $\frac{1}{|h_{sr}|}$, $\frac{1}{|h_{rd}|}$ or $\frac{1}{|h_{sr}||h_{rd}|}$; therefore, three selection criteria (SC) are set as follows:

$$SC1 = \arg\min_{\mathrm{r}\in\mathrm{R}}(\frac{1}{|h_{sr}|}) \tag{14}$$

$$SC2 = \arg\min_{\mathrm{r}\in\mathrm{R}}(\frac{1}{|h_{rd}|}) \tag{15}$$

$$SC3 = \arg\min_{\mathrm{r}\in\mathrm{R}}(\frac{1}{|h_{sr}|\,|h_{rd}|}) \tag{16}$$

Equations 14-16 are used as selection criteria to choose the cooperating relay among the surrounding terminals. While the first criterion depends on the quality in the first transmission phase, the second depends on the link quality in the second transmission phase. The third criterion with computational overhead, i.e. R multiplications, considers the end-to-end link quality for both transmission phases. Each of these criteria has a different impact on either maximizing the capacity or the error performance, as illustrated in the results.

It is clear that the SC3-based selection scheme requires R multiplications over SC1- and SC2-based schemes, i.e., each criterion demands a different computational complexity. Repeating the procedure in (10) based on the existence of interference as in Figure 1, the utilization can be leveraged as follows:

$$\min_{r \in R}[\frac{\xi |h_{Ir}|^2}{|h_{sr}|^2}+\frac{\vartheta_r}{|h_{sr}|^2}+\frac{\partial_r}{|h_{rd}|^2}+\frac{\xi \partial_r |h_{Ir}|^2}{|h_{sr}|^2 |h_{rd}|^2}+\frac{\vartheta_r \partial_r}{|h_{sr}|^2 |h_{rd}|^2}]$$

and

$$\xi = P_I/P_s \tag{17}$$

and/or

$$\min_{r \in R}[\frac{\xi |h_{Ir}|^2}{|h_{sr}|^2}+\frac{\vartheta_r}{|h_{sr}|^2}]$$

and/or

$$\min_{r \in R}[\frac{\xi^2 |h_{Ir}|^4}{|h_{sr}|^4}+\frac{2\vartheta_{r\xi} |h_{Ir}|^2}{|h_{sr}|^4}+\frac{\partial_r \xi |h_{Ir}|^2}{|h_{sr}|^2 |h_{rd}|^2}+\frac{\vartheta_r^2}{|h_{sr}|^4} +\frac{\xi^2 \partial_r |h_{Ir}|^4}{|h_{sr}|^4 |h_{rd}|^2}+\frac{2\xi \partial_r \vartheta_r |h_{Ir}|^2}{|h_{sr}|^4 |h_{rd}|^2}+\frac{\vartheta_r \partial_r}{|h_{sr}|^2 |h_{rd}|^2} +\frac{\vartheta_r^2 \partial_r}{|h_{sr}|^4 |h_{rd}|^2}]$$

Therefore, the selection criteria SC1 and SC3 can be investigated here, in addition to

$$SC4 = \arg\min_{r\in R} |h_{Ir}|) \tag{18}$$

$$SC5 = \arg\min_{r\in R} \frac{|h_{Ir}|}{|h_{sr}|}) \tag{19}$$

$$SC6 = \arg\min_{r\in R} \frac{|h_{Ir}|}{|h_{sr}|\,|h_{rd}|}) \tag{20}$$

Similarly, these criteria depend on maximizing either $\frac{1}{|h_{Ir}|}$, $\frac{|h_{sr}|}{|h_{Ir}|}$ or $\frac{|h_{sr}||h_{rd}|}{|h_{Ir}|}$. The SC3 and SC5 criteria impose R multiplication/division as an additional overhead in the selection process over what is required in the SC1, SC2 and SC4 criteria. The last criterion, SC6, requires a $2R$ overhead process to complete the selection procedure.

SC3 is expected to be more efficient than the other criteria because $|h_{sr}|\,|h_{rd}|$ appears more frequently in the above analyzed terms in the presence of interference. The simulation study demonstrates its crucial role in the recording of improvements.

Now, if an interference impact is considered in both transmission phases, the last three selection criteria are replaced with the following criteria:

$$SC4^{\wedge} = \arg\min_{r\in R} |h_{Ir}|\,|h_{Id}|) \tag{21}$$

$$SC5 = \arg\min_{r\in R} \frac{|h_{Ir}|}{|h_{sr}|}) \tag{22}$$

$$SC6^{\wedge} = \arg\min_{r\in R} \frac{|h_{Ir}|\,|h_{Id}|}{|h_{sr}|\,|h_{rd}|}) \tag{23}$$

In addition, to a new criterion

$$SC7 = \arg\min_{r\in R} \frac{|h_{Id}|}{|h_{rd}|}) \tag{24}$$

In the case of the cooperation of more than one partner in the transmission process, to provide virtual multiple antenna system, the lower bound of the overall link capacity with K selected cooperating partners is defined as

$$C_{min} = \frac{1}{2}\log_2[(1+\min_{r \in k} \frac{|h_{sr}|^2}{\xi |h_{Ir}|^2+\vartheta_r})\,(1+\sum\nolimits_{r\in K} \zeta_r)] \tag{25}$$

In the equation above, the minimum transmission capacity in the first phase is considered because it is the bottleneck in the end-to-end communication link.

In this work, a simulation study is conducted to investigate the efficacy of the selection criteria described above in improving the error performance and the transmission capacity. A constant total transmission power P_{tot} is considered in the cooperation scheme, where $P_s = P_r = \frac{P_{tot}}{K+1}$ is used to avoid any additional resource consumption by involving more cooperating partners to deliver the information to the intended destination.

B. DF RELAY SCHEME

For the DF relay scheme, it is assumed that an interference signal could overlap with the delivered signal in both transmission phases. Because a terminal that correctly decodes the message from the source can be a candidate for cooperating and relaying the signal to the destination, we consider the interference in the second transmission phase. The total capacity for the described DF relay scheme is similar to that defined earlier in the AF relay scheme; however, ζ_r for the second transmission phase is given by

$$\zeta_r = \frac{|h_{rd}|^2}{\xi |h_{Id}|^2+\partial_r} \tag{26}$$

and substituting the expression into (12) results in

$$C = \frac{1}{2}\log_2[1+\frac{|h_{rd}|^2}{\xi |h_{Id}|^2+\partial_r}+\frac{|h_{sr}|^2}{\vartheta_r}+\frac{|h_{rd}|^2 |h_{sr}|^2}{\xi \vartheta_r |h_{Id}|^2+\partial_r \vartheta_r}] \tag{27}$$

To maximize the system utilization, different selection criteria are investigated to evaluate the efficacy of each. Since the candidate users to play as a relay have already achieved error-free decoding, the interference in the first time slot is ignored in the selection process. However, the transmission link in the first phase is also evaluated to demonstrate its impact on either error performance or channel capacity. The selection criteria SC1, SC2 and SC3 are used in addition to the following:

$$SC4^{*} = \arg\min_{r\in R} |h_{Id}|) \tag{28}$$

$$SC6^{*} = \arg\min_{r\in R} \frac{|h_{Id}|}{|h_{sr}|\,|h_{rd}|}) \tag{29}$$

$$SC7 = \arg\min_{r\in R} \frac{|h_{Id}|}{|h_{rd}|}) \tag{30}$$

The computational complexity of SC4* is equivalent to that for SC1, SC2 and SC4, and the complexities of SC3, SC5, $SC4^{\wedge}$ and SC7 are equivalent. SC6 and $SC6^{*}$ impose similar overhead computations. $SC6^{\wedge}$ requires a 3R overhead process.

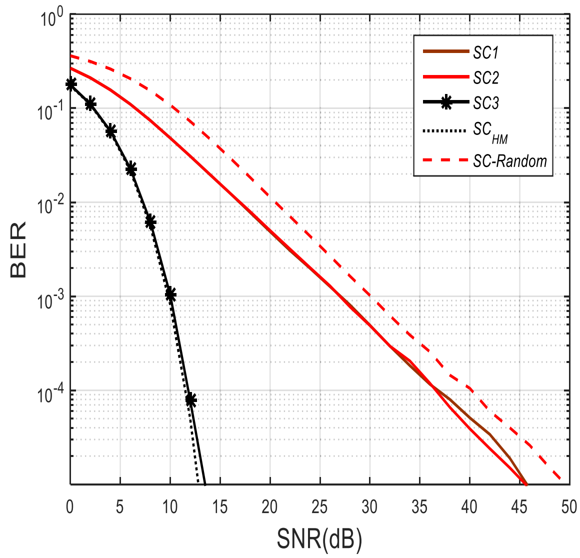

FIGURE 2. Error performance with a single partner in an interference-free environment.

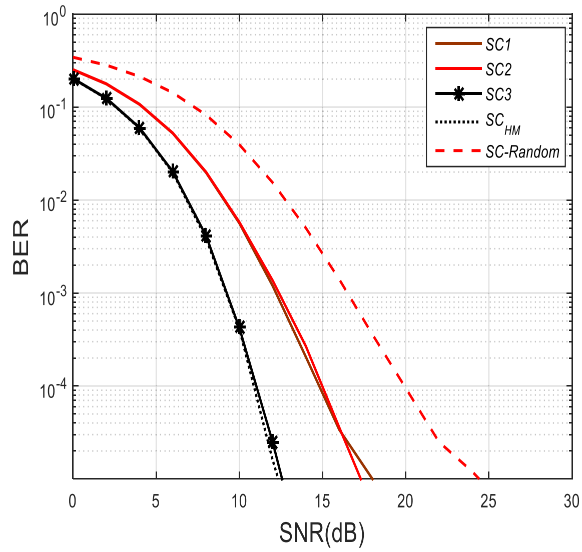

FIGURE 3. Error performance with four selected partners in an interference-free environment.

III. SIMULATION RESULTS

A computer simulation is conducted to study the performance of the above-described cooperation scheme and evaluate the efficacy of the different selection criteria for the cooperator(s). The simulation is set up based on the system model described in Figure 1. The existence of 36 potential terminals that are willing to work as a relay is assumed. Binary phase shift keying (BPSK) modulation is applied in the simulated system. The results are compared with the harmonic mean criterion presented in [3], which is given as

$$SC_{HM} = \arg\max_{r\in R} \frac{|h_{sr}|\,|h_{rd}|}{|h_{sr}| + |h_{rd}|}) \tag{31}$$

The selection criterion considers both source to relay and relay to destination transmission links and imposes $3R$ operations, i.e., it has the highest computational complexity, similarly to SC6^. The study is conducted in terms of the error performance and the channel capacity.

A. ERROR PERFORMANCE

1) ERROR PERFORMANCE IN AN AF RELAY SCHEME

The results shown in Figure 2 compare the error performance in an interference-free environment when the individual selection criteria described in the previous section are used to choose a single cooperator from the available terminals.

The selection criteria SC1 and SC2 yield nearly indistinguishable outcomes, while SC3 and SC_{HM} yield equivalent performance improvements; however, SC_{HM} requires higher computational complexity. Furthermore, the performance with the random selection of a cooperator, i.e., the nonselection policy with zero computation overhead, is studied to portray the gain at the expense of computation complexity. The results show gains of 7.5 dB and 32.5 dB at an error rate of 10^{-4} achieved by SC1/SC2 and SC3/SC_{HM}, respectively, compared to random selection records.

The simulation results in Figure 3 focus on the choice of multiple partners from the 36 available terminals and present the error performance versus SNR in an interference-free environment when four partners are employed to receive the transmitted signal from the source and forward it to the destination using an AF protocol.

Different combining techniques, such as selection combining, equal gain combining, and maximal ratio combining, have been applied in the literature. For instance, when complexity is a constraint, SC is more suitable, while when high performance is demanded, Maximum Ratio Combining (MRC) is the optimal technique because it uses each of the available diversity branches in a co-phased and weighted manner to obtain the highest achievable SNR at the destination [26]. The MRC technique is applied at the receiver to combine the delivered signals under the assumption that the channel state information of the transmission links in the second phase is available.

With four selected terminals participating in the cooperation scheme, the results show a diversity gain that produces a significant improvement in error performance. The improvement is more distinct in the schemes based on SC1, SC2 or random selection. As illustrated in section II, the transmission power is equally distributed between the source and all the selected partners, and the total consumed power required to deliver the information is equivalent to that consumed when a single selected partner forwards the signal.

Although interference-free transmission does not represent a real-life scenario, it has been extensively considered in previous studies.

To portray the impact of interference on the achievement of a cooperation scheme, Figure 4 investigates the performance when an interference signal overlaps with the transmission in the first phase with a signal-to-interference power ratio of 4-6 dB [27]. The selection criteria SC4, SC5, and SC6 are

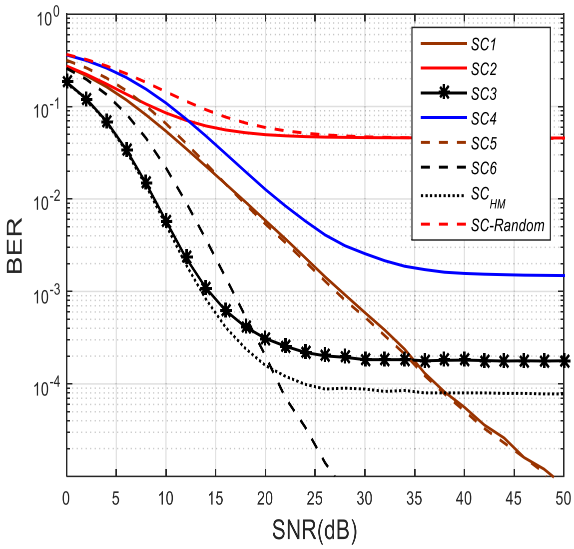

FIGURE 4. Error performance with a single partner and an interference signal overlap with the transmission in the first phase.

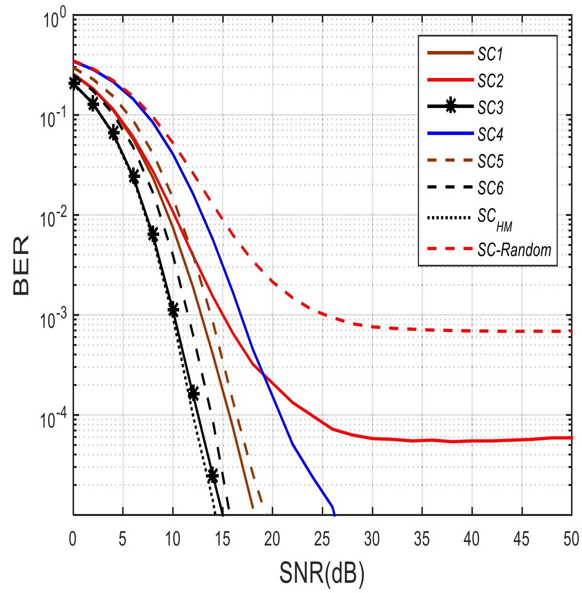

FIGURE 5. Error performance with four partners and an interference signal overlap with the transmission in the first phase.

included in the study. In the 0-20 dB SNR region, the channel noise generally dominates the impairments, where SC3 and SC_{HM} records a higher efficacy during the selection process. However, they achieve a flattened error rate at higher SNRs, such as SC1 and SC4.

The first transmission link between the source and the cooperator represents the bottleneck in the end-to-end communication because of the impact of interference; therefore, SC1 and SC5 offer better performance at high SNR. SC6, which has computational complexity equivalent to that of SC_{HM}, results in a more robust communication scheme. With the existence of an interference signal, the need for a suitable selection process is greater when a nonselection policy does not achieve the desired outcomes, as clearly indicated in the figure.

To overcome the impact of interference and conserve the users' energy with lower overhead and lower computational complexity, the use of multiple partners in the cooperation scheme is suggested. As previously stated, each involved terminal consumes less energy than it did previously when a single partner was selected. Figure 5 shows the remarkable improvement in the performance of all the selection criteria in terms of the error rate that occurs when four partners are employed in the cooperation. The results portray the special achievements of the SC3, SC6, and SC_{HM} selection criteria; when these criteria are used, the error rate is close to the lower error rate recorded in an interference-free environment.

The results demonstrate the efficacy of incorporating more terminals in the cooperation scheme and the efficacy of the applied selection criterion.

Referring to (20), the criterion SC6 demands a state of interference link in addition to the end-to-end transmission link, while only the latter is demanded by the SC3- and SC_{HM}-based schemes. On the other hand, the SC6- and SC_{HM}-based schemes employ two times and three times, respectively, the computational complexity of that used in the SC3 scheme. Therefore, the selection process does not impose further complexity on the presence of interference, and its state information is not demanded when multiple relays forward the signal. Therefore, cooperating multiple partners would reduce the complexity of the selection process.

A simulation study is conducted to evaluate the efficacy of the selection criteria in the cooperative scheme when the interference impacts the transmission in both transmission time slots. The results shown in Figure 6 illustrate the degradation in error performance using different relay selection criteria, although the SC4 and SC6 criteria employ higher computational complexity. However, SC3 and the harmonic mean criteria-based scheme survive the interference when four surrounding terminals cooperate in the transmission process. The SC_{HM}-based selection scheme imposes a $3R$ computation process over a scheme based on SC3. In general, the results demonstrate that SC3 provides a better trade-off between selection complexity and performance. For instance, less energy consumption is needed for SC3 to achieve the same level of BER compared to random selection.

2) ERROR PERFORMANCE IN A DF RELAY SCHEME

The results presented in Figures 7 and 8 represent the evaluation of the previously studied selection criteria in a DF relay network. An interference signal disturbs the intended transmission in both time slots. First, one user is selected to cooperate in the transmission by decoding, re-encoding and forwarding the signal to the destination. The complex selection criteria SC6 and SC7 use interference state information and achieve a lower error rate at the expense of high computational complexity (Figure 7).

Later, four of the candidate users are selected to cooperate in the transmission. Coherent combining of the received

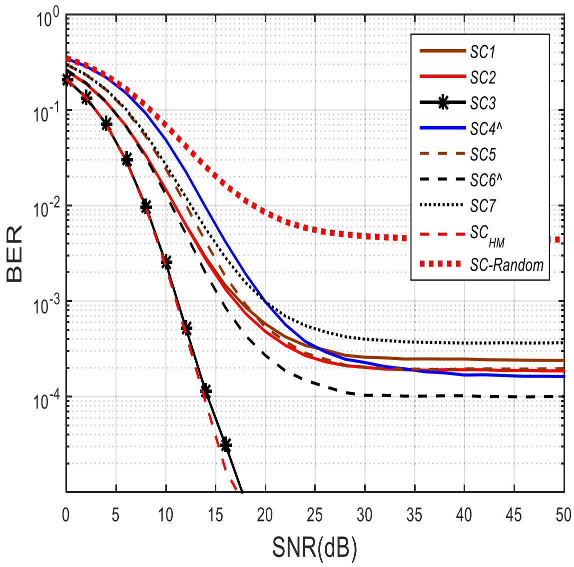

FIGURE 6. Error performance with four partners and an interference signal in both transmission phases.

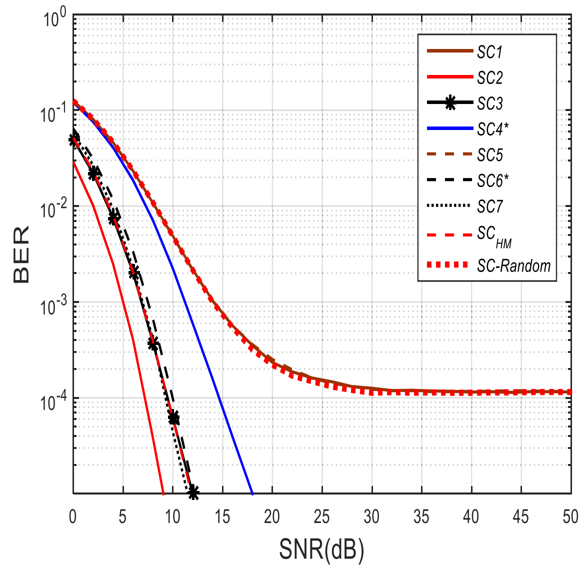

FIGURE 8. Error performance in the DF scheme with four partners and an interference signal overlap with the transmission in both phases.

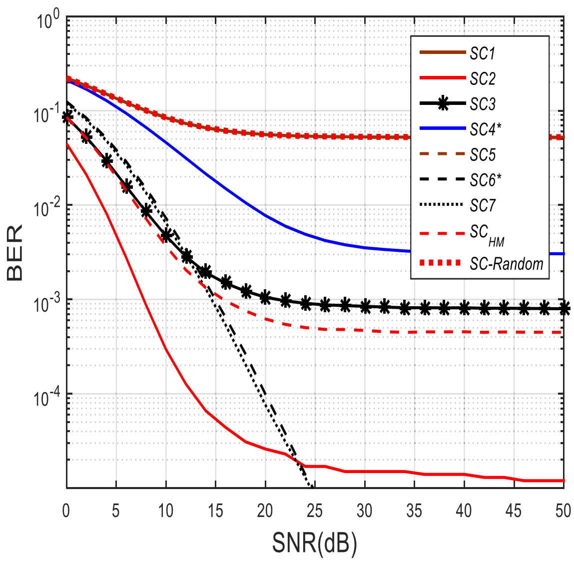

FIGURE 7. Error performance in the DF scheme with a single partner and an interference signal overlap with the transmission in both phases.

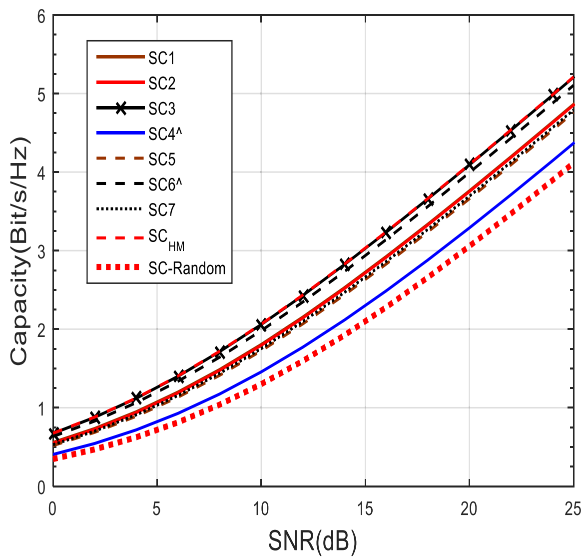

FIGURE 9. Channel capacity with four partners and an interference signal overlap with both transmission phases in the AF scheme.

signals using MRC at the destination is assumed. It can be seen that the simple criterion SC2, which maximizes the link quality in the second transmission phase regardless of the interference state, records a lower error rate (Figure 8), while more complex criteria achieve less.

The results again demonstrate the efficacy of selecting multiple relays rather than a single relay. The study shows that even the surrounding users who suffer from interference can be exploited as relays.

B. CHANNEL CAPACITY

In addition to the error performance, the channel capacity versus SNR of the cooperative framework is presented in Figure 9 using the previously discussed selection criteria in an AF relay network. The channel capacity reveals the error-free transmission rate over the bandwidth. The lower bound of the capacity is calculated.

As clearly indicated by the simulation results, a selection criterion changes the reachable channel capacity, and SC3 and SC_{HM} record the highest capacity in the cooperation scheme when four surrounding users are used as cooperating AF relays.

Figure 10 illustrates the lower bound of the channel capacity in the framework using four selected DF relays. In DF, the second transmission phase plays a large role in the capacity maximization problem, and the results demonstrate the efficacy of SC2 in leveraging channel utilization. The level of complexity of this criterion is lower than that of the proposed SC3 in AF, but the DF scheme by itself involves a more complex process.

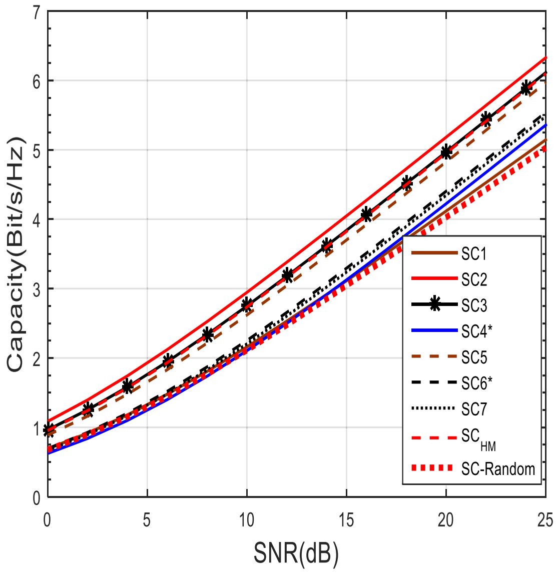

FIGURE 10. **Channel capacity with four partners and an interference signal overlap with both transmission phases of a DF scheme.**

IV. CONCLUSION

In this paper, we propose an efficient single and multiple partner selection criterion in a cooperative scheme. The study considers a single source and destination with several terminals in between that collaborate as potential relays to support the communication process in AF and DF schemes. The total transmission power P_{tot} is constrained by the source, and the K selected partners each consume energy equally: $\frac{P_{tot}}{K+1}$. The results clearly demonstrate the efficacy of SC3-based schemes using the AF relay type, in which the quality of the end-to-end transmission link, regardless of the interference state, is a sufficient and efficient criterion for the selection of partners from terminals suffering from interference.

In the investigated DF relay scheme, regardless of the interference impact, the quality of the link in the second transmission phase plays a crucial role as a criterion in the selection of multiple partners to cooperate in the transmission process. The results demonstrate that the impact of interference can be mitigated by exploiting the diversity gain by selecting multiple relay partners. Furthermore, because the selection criterion is independent of the interference state information, the entire selection process is not complicated and plays an important role in enhancing network capacity and error performance.

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