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ORIGINAL ARTICLE

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Polar coded cooperative with Plotkin construction and quasi-uniform puncturing based on MIMO antennas in half duplex wireless relay network

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Abstract
Recently, polar code has attracted the attention of many scholars and has been developed as a code technology in coded-cooperative communication. We propose a polar code scheme based on Plotkin structure and quasi-uniform punching (PC-QUP). Then we apply the PC-QUP to coded-cooperative scenario and built to a new coded-cooperative scheme, which is called PCC-QUP scheme. The coded-cooperative scheme based on polar code is studied on the aspects of codeword construction and performance optimization. Further, we apply the proposed schemes to space–time block coding (STBC) to explore the performance of the scheme. Monte Carlo simulation results show that the proposed cooperative PCC-QUP-STBC scheme can obtain a lower bit error ratio (BER) than its corresponding noncooperative scheme.

KEYWORDS
coded-cooperation, Plotkin construction, polar code, quasi-uniform puncturing (QUP), space–time block coding (STBC)

1 | INTRODUCTION

The 5G communication system require an ultra-high-speed information transmission, which requires increasing system capacity and reducing system complexity. Diversity is an effective measure against channel fading in wireless communication, which can improve the capacity of communication systems. Various kinds of diversity techniques have been introduced in many literatures in terms of time, frequency, spatial, and other variants in order to overcome negative effects of channel fading [1, 2]. By using diversified signal processing technique, the receiver obtains multiple copies of the transmitted signal from the source [3]. Multiple input multiple output (MIMO) spatial diversity is a commonly used implementation. But it is difficult to install multiple antennas in a mobile terminal in practical applications.

Recently, much research has been conducted on a wireless cooperative communication system using large-scale relay [4]. The effect of virtual MIMO can be achieved with cooperative transmission between users. Coded-cooperation transmission is one of cooperative transmission, which has been studied by many scholars these years. Sendonaris et al. [5] proved that coded-cooperation technique can get a higher data rate when compared to a noncooperative communication system. Wang and Hao [6] did some research on the performance analysis of coded cooperative communications in a cluster of relays. The literature [7] proposed a coded-cooperative scheme of polar codes, which is applied for high-reliability and low-user complexity applications.

As for implementation of encoding, advanced encoding technology that can approach the Shannon limit transmission should be adopted to meets the higher speed demand for information transmission [8]. The polar code proposed by Arikan in 2009 in literature [9] is a code technology in which correction was proven to approach Shannon extreme. Polar code is an error-correcting code proposed that can theoretically achieve the Shannon limit. Polar codes are suitable for arbitrary binary discrete memoryless channels and have a better performance on continuous additive white Gaussian noise channels [10–12]. Besides, polar code is used in some communication systems. The cooperation of polar scheme based on Plotkin firstly proposed in reference [13]. Later, the literature [14] proposes a two-stage blind detection scheme based on Plotkin structure of polar code for 5G communication [14]. Further, a polar coded-cooperative scheme on the basis of literature [13] is proposed, which combined to spatial modulation [15]. However, these schemes cannot achieve significant system gains in communication channels. In order to propose a high-gain polar cooperative scheme, this paper conducts a more comprehensive exploration on the cooperative system of polar codes from two aspects: codeword construction and performance optimization.

In this letter, some analogous algorithms were evolved to improve the BER performance and at the expense of lowering the spectrum efficiency. The structure of codewords plays an important role in cooperative communication scheme. Currently, relevant literature [16–18] has pointed out that codewords can be implemented through puncturing. The literature [18] proposed that the method of quasi-uniform puncturing (QUP) can be applied to modify the information bits set to raise performance. Then, the QUP method with 50% bits punctured method can be applied in cooperation communication to further raise the cooperation performance.

Recently, some cooperative communication based on polar code schemes [19, 20] have been proposed. This letter focuses on the Plotkin construction method adopted in literature [13], which has a poor performance in slow fading channel. In order to get a better performance, we proposed a polar coded-cooperation based on Plotkin construction and QUP (PCC-QUP), we perform Plotkin construction on polar's inverted codewords and obtain a code cooperative scheme on inverted sub-codewords, which significantly improves the performance of the polar coded-cooperative in the fading channel. Further, we apply the scheme to STBC system to explore the performance of the scheme in MIMO antenna systems. The novel contributions of this manuscript are depicted:

- Firstly, we realize the Plotkin construction of polar code by using QUP (PC-QUP), which is different with the literature [13]. The decoded characteristics of the inverse codewords are analyzed; meanwhile, the QUP method is introduced to improve the synergy of polar codes.
- Then we apply the PC-QUP to coded-cooperative scenario and built to a new coded-cooperative scheme, which is called PCC-QUP scheme.
- The polar coded-cooperative scheme is coded with MIMO system over Rayleigh fading channel to exploring the performance of multi-antenna input and output information transmission.

In Section 2, the coded-cooperative communication model is depicted. In Section 3, we explain the principles of polar code combined to the Plotkin construction of codewords [13]. Section 4 show a polar coded-cooperation STBC model on the basis of Plotkin construction and QUP (PCC-QUP-STBCs). Section 5 presents the Monte Carlo simulation results and comparisons of the proposed schemes over Rayleigh channels. In the end, Section 6 gives the conclusion of the paper.

2 | MODEL

As depicted in Figure 1, parts of a codeword will be allocated and transmitted between users in a coded-cooperation system. The code rate of codewords in cooperative scheme is the same as that in the corresponding noncooperative system, which will not take up additional system resources.

In the first time slot, the source performs channel coding on K bits of information to generate N bits of codeword information C (code rate K/N). Then through a certain codeword construction method to divide the N bits codeword into two N_1 bits sub-codeword, C_1 broadcast the C_1 (code rate K/N) to the destination node and relay node in its own multiple access channel. The

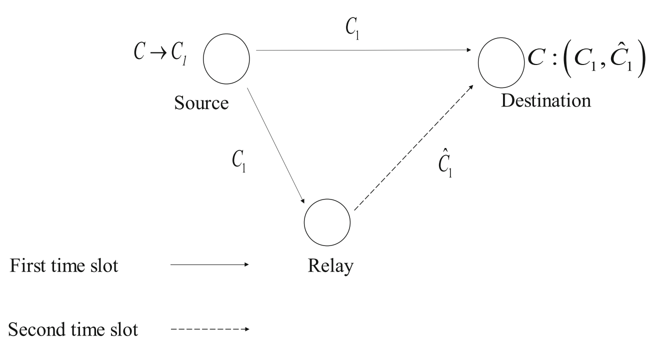

FIGURE 1 The coded-cooperation model.

coded-cooperation scheme in this article consists of a source node, a relay node, and a destination node. The interactive channel between the two nodes is Rayleigh channel with white Gaussian noise.

The source node, relay node, and destination node are represented by the numbers 0, 1, and 2, respectively. The system adopts BPSK modulation, and the output signal after coding and modulation of user i $(i = 1, 2)$ is set as is x_i; then the information sequences received by the receiver j $(j = 0, 1, 2)$ can be shown as

$$y_{ij} = h_{ij}x_i + n_{ij}. \tag{1}$$

The channel code of each user in Figure 1 adopts the polar code up to the Shannon limit transmission. We propose a PCC-QUP scheme; we perform Plotkin construction on polar's inverted codewords and obtain a code-cooperative method based on inverted subcodewords, which significantly improves the performance of it in the fading channel. Further, we apply the scheme to STBC system to explore the performance of the scheme in MIMO antenna systems.

3 | PLOTKIN CONSTRUCTION OF POLAR CODE WITH QUP

The principles construction of Plotkin based on polar code and QUP is depicted in this section. Simply put, Plotkin's code construction is a code reconstruction technology in which subcodes generated from the same mother word are connected to create a new code word. Polar code firstly proposed by Arikan [11] and its generator matrix can be shown as

$$G = B_N F^{\bigotimes n}, \tag{2}$$

where $N = 2^n$ represents codeword's length, B_N represents a bit flip matrix and $F = \begin{bmatrix} 1 & 0 \\ 1 & 1 \end{bmatrix}$, and $\bigotimes n$ represents Kronecker product of order n and $F^{\bigotimes n} = F \bigotimes F^{\bigotimes n-1}$. Set $u_0^{N-1} = (u_0, u_1, \cdots, u_{N-1})$ be the original sequence; $x_0^{N-1} = (x_0, x_1, \cdots, x_{N-1})$ is the generated codeword sequence. Thus, the codeword of polar code be shown:

$$x_0^{N\text{-}1} = u_0^{N-1}G. \tag{3}$$

There are two main methods for the decoding of polar code: successive cancellation (SC) decoding and belief propagation (BP) decoding [20]. SC decoding has lower complexity compared with BP decoding. Thus, we use SC decode method for the cooperation system in this article.

3.1 | Plotkin construction of codewords

Let C_1 and C_2 be two linear block codes, then let K_1 and K_2 be their dimensions, respectively, and their lengths are n_1 and n_2. Their minimum Hamming distances are d_1 and d_2. Thus, we can get a new and longer linear block code $\overline{C}_3$ based on the Plotkin construction [20].

$$C_3 = \{v + u|u\}, \tag{4}$$

where $u \in C_1$, $v \in C_2$ and $|$ indicate cascade. C_1 and C_2 has identical lengths; then $n_1 = n_2$. The dimension of $\overline{C}_3$ is $K_1 + K_2$. Its minimum Hamming distance is $d_1 + d_0$, where d_0 is the minimum Hamming distance of code $\{v + u\}$.

3.2 | Plotkin construction of polar code

The generator matrix G of polar code can be shown as

$$G = B_N G^{'}, \tag{5}$$

where $G = F^{\bigotimes n}$, $F = \begin{bmatrix} 1 & 0 \\ 1 & 1 \end{bmatrix}$, $n = lbN$, and N represents codeword length. $G^{'}$ can be shown as follows:

$$G^{'} = \begin{pmatrix} G^{'} & 0 \\ G^{'} & G^{''} \end{pmatrix}, \tag{6}$$

where $G'' = F^{\bigotimes (n-1)}$. The encode of the polar code can be shown as

$$\begin{aligned} x &= uG = uB_N G^{'} = uG^{'}B_N \\ &= \left(u_A G_A^{'} \bigoplus u_{A^c} G_{A^c}^{'}\right) B_N = u_A G_A^{'} B_N. \end{aligned} \tag{7}$$

In (7), x represents the generated codeword, $u = (u_A, u_{A^c})$ represents the information, which will be encoded A, and complement A^C represents the indices set of information bits and dormant bits, respectively. Let $u_{A^c} = 0$ in polar code. The row indices of $G_A^{'}$ in the set A and the row indices of $G_{A^c}^{'}$ in the complement set A^C.

We let

$$\begin{cases} A_1 = \left\{ i \mid i \in A, 0 < i \le \dfrac{N}{2} \right\}, \\ A_2 = \left\{ i, i \in A \middle| \dfrac{N}{2} < i \le N \right\}. \end{cases} \tag{8}$$

Then

$$x = u_A G_A^{'} B_N = u_A \begin{pmatrix} G_{A_1}^{'} \\ G_{A_2}^{'} \end{pmatrix} B_N, \tag{9}$$

where $G_{A_1}^{'}$ and $G_{A_2}^{'}$ are the matrix extracted from the matrix $G^{'}$ and their rows indices are in A_1 and A_2, respectively.

By (9), we can get

$$G_{A_1}^{'} = (G_1 \ 0), \tag{10}$$

$$G_{A_2}^{'} = (G_2 \ \ G_2), \tag{11}$$

G_1 denotes the matrix selected from $G^{'}$, in which row indices in A_1 and column indices in the set $\{i|1 \le i \le N/2\}$. G_2 denotes the matrix selected from $G^{'}$, whose row indices in A_2 and column indices in the set $\{1 \le i \le N/2\}$. The matrix $G_{A_1}^{'}$ may have two cases: non-empty matrix or empty matrix. Thus, $G_{A_1}^{'}$ shall have two codeword structure.

1. $G_{A_1}^{'}$ is a non-empty matrix:

$$\begin{aligned} x &= u_A G_A^{'} B_N = u_A \begin{pmatrix} G_{A_1}^{'} \\ G_{A_2}^{'} \end{pmatrix} B_N = u_A \begin{pmatrix} G_1 & 0 \\ G_2 & G_2 \end{pmatrix} B_N \\ &= (u_{A_1}, u_{A2}) \begin{pmatrix} G_1 & 0 \\ G_2 & G_2 \end{pmatrix} B_N \\ &= \left\{ u_{A_1} G_1 \bigoplus u_{A_2} G_2 | u_{A_2} G_2 \right\}. \end{aligned} \tag{12}$$

Let $V_1 = u_{A_1} G_1$, $V_2 = u_{A_2} G_2$; then the generated codeword can be expressed as a Plotkin structure; thus,

$$x = \{v_2 + v_1 | v_2\} B_N = x^{'} B_N, \tag{13}$$

$$x^{'} = \{v_2 + v_1 | v_2\}. \tag{14}$$

B_N only serves as a bit reversal function, without affecting the structure of the codeword.

2. $G_{A_1}^{'}$ is an empty matrix.

In this case, the form of $G_A^{\prime}$ $G_A^{'}$ is shown as

$$G_A^{'} = \left(G_2^{'} \ \ G_2^{'} \right), \tag{15}$$

$G_A^{'}$ denotes the matrix with indices of rows in A. G_2 is a matrix extracted from the matrix with indices of row in A_2 and indices of column in the set $\{i|1 \le i \le N/2\}$. The process of encode of the polar code as

$$x = u_A G_A^{'} B_N = u_A \left(G_2^{'} \ \ G_2^{'} \right) B_N = \left\{ u_A G_2^{'} | u_A G_2^{'} \right\} B_N. \tag{16}$$

Thus, a code $v = u_A G_2^{'}$ generated by $G_2^{'}$ can directly constitute a polar code's whole codeword.

$$x = \left[v_2^{'}, v_2^{'} \right] B_N. \tag{17}$$

3.3 | The construction of Plotkin of polar code based on QUP

The codewords will lose its half of information codewords in the construction of Plotkin based on polar code. The position of the missing codeword in part C_1 as the same as the position of using QUP algorithm with puncturing of 50% bits. Meanwhile, the changing on the dependence relationships between each information bit also is same. A portion of codeword's information bits is lost because of using QUP, which shall transform the dependence relationships between bits information. The article [18] points out using QUP can rewrite the information bits set to upgrade decode performance.

Thus, using QUP with 50% bits punctured can modify the information bits set of the whole codeword in cooperative scheme to further perfect the cooperation performance, detailed as follows:

1. A QUP vector P of 50% puncturing ratio should be adopted as a puncturing vector, which applied to correct the bits set A of ordinal codeword to get a new bit set $A^{'}$.
2. The new set $A^{'}$ on the basis of revising of QUP shall be constructed using the method at Section 3.2; then an empty matrix $G_{A^{'}}^{'}$ appears. So, the structured $G_{A^{'}}^{'}$ becomes the following form:

$$G_{A^{'}}^{'} = \left(G_2^{''} \ \ G_2^{''} \right), \tag{18}$$

where $G_{A^{'}}^{'}$ is the matrix whose indices of rows in $A^{'}$ and indices of column in the set $\{i|1 \le i \le N/2\}$. The structure of the division codeword will be carried out according to the method in Section 3.2.

The algorithm of QUP is shown as follows.

Algorithm: Quasi-uniform puncturing
Enter: Punching vector $\boldsymbol{A}$
Output: Row selection vector $\boldsymbol{R}$

set $J_0^{(i)} = C_i(c \in C)$;
for $0 \le i \le N-1$
 for $0 \le j \le N-1$
  $j \to \langle b_0 b_1 \cdots b_{n-1} \rangle$;
  for $m = 0, \cdots, n-1$
   for $k = 0, 1, \cdots, \frac{N}{2^{m+1}} - 1$
    if $b_m = 0$
     $J_{m+1}^{(K)} = J_m^{(2K)} \wedge J_m^{(2K+1)}$;
    else
     $J_{m+1}^{(K)} = J_m^{(2K)} \vee J_m^{(2K+1)}$;
    end
   end
  end
  if $J_n^0 = 1$, then $j \in R$; otherwise, $j \notin R$;
 end
end

where $\wedge$ denotes an operation of logical AND, $\vee$ denotes an operation of logical OR, $j \to \langle b_0 b_1 \mathrm{L}\ b_{n-1} \rangle$ denotes the binary number form of j, b_0 denotes the most powerful bit, b_{n-1} denotes the least powerful bit, and N denotes the codeword length. A is a punctured vector with a length of N, the position of the codeword's elements in A are set to 0, while the other positions all are 1.

The code length and the code rate of the whole code are N and R, respectively. Take the situation of G'_{A_1} as an example, the main steps of Plotkin construction of polar code based on QUP as follows:

1. Let the length of codeword $N = 2n$ and determine the code rate R in this cooperative scheme.
2. Generate the inverted code matrix $G' = F^{\otimes m}$ of polar code, where $m = \mathrm{lb}N$.
3. Compute Z parameter of each code bit and determine the information bits set A and the dormant bits set A^C. Then, using QUP vector P with puncturing ratios of 50% to correct the set A of the whole codeword and get the new information bits set A'.
4. The bits set A' after the QUP corrected will be reconstructed using the method in Section 3.2; then an empty matrix G'_{A_1} appears.
5. Remove the rows of G' in which row indices in A^C, then to get the coding matrix.
6. Let all rows of which column elements from $n+1$ to $2n$ to be set to 0 in the front of the matrix G' to obtain G''. Finally extract the coded sub-matrices G_2 from G'' to yield the short codes v_2; we get $x = [v_2, v_2]B_N$.

4 | POLAR CODED-COOPERATION SCHEME BASED ON PLOTKIN CONSTRUCTION AND QUP

In this section, we will introduce the construction process of the PCC-QUP-STBC communication scheme in detail. The proposed PCC-QUP-STBCs need two time slots in a complete transmission. The PCC-QUP-STBCs are depicted in Figure 2. The whole transmission system includes three parts: source node (SN), relay node (RN), and destination node (DN). The cooperation port SN and RN are similar to the port of user 1 and user 2 as depicted in Figure 1, respectively. The cooperation port DN is also similar to the port of base station as depicted in Figure 1.

4.1 | Polar encoding using Plotkin construction with QUP

Let C (N, K, α) be a polar code; we use QUP algorithm with ratios of 50% to generate a new row selection vector and then calculate the reliability of polarized channels to determine the information bits and the frozen bits based on channel parameters using Gaussian approximation (GA). Then the length of information bits is $N/2$, and the code x obtained based on Plotkin construction method is denoted by C can be expressed as (19) and (20):

$$x = u_A G_A B_N = u_A (G_2 \ \ G_2) B_N = \{u_A G_2 | u_A G_2\} B_N, \quad (19)$$

$$x = [v, v], \quad (20)$$

where C has a code rate $R_C = K/N = 1/2$.

4.2 | PCC-QUP-STBC scheme

The Plotkin construction of polar code is naturally suitable for the framework of typical cooperative transmission scenarios. Therefore, the cooperation model proposed in this paper can be successfully carried out.

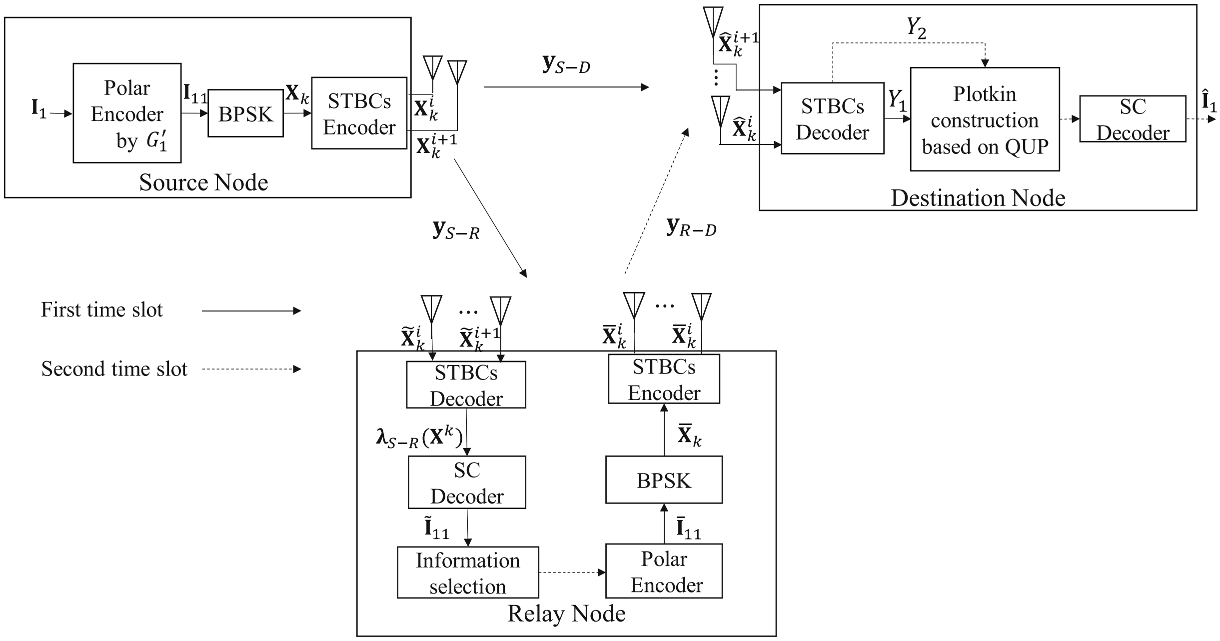

FIGURE 2 The construction of PCC-QUP-SBTC scheme.

The complete communication of a message bits $\mathbf{I}_1$ from the SN to DN needs two successive time slots.

Let our polar code's parameter be $P\,(n,\,k,\,a)$; we use the vector P of QUP algorithm with a punching ratio of 50% to carry out the correction of the overall codeword information of set A and then get a new set $A^{'}$. Then, we conduct the Plotkin construction of Polar code $P\,(n,\,k,\,a)$ to get a new part codeword parameter $P_1(n_1,k_1,\alpha_1)$, where the length of n_1 is half of N. During first time slot, the SN uses polar code $P_1(n_1,k_1,\alpha_1)$ to encode the information sequences $\mathbf{I_1}$ and get a new codeword $\mathbf{I}_{11}$. Then $\mathbf{I}_{11}$ is sent to being BPSK modulation and get the signal $\mathbf{X}_k$.

Then $\mathbf{X}_k$ is sent to STBCs-Encoder to generates space time block symbols $\mathbf{X}_k^i$ and $\mathbf{X}_k^{i+1}$. These two STBCs are broadcasted over the radio channel towards both RN and DN. The sequence received $\mathbf{y}_{S-R}$ at the RN during the first time slot as follows:

$$\mathbf{y}_{S-R} = \mathbf{H}_{S-R}\mathbf{X}_k + \mathbf{N}_{S-R}, \tag{21}$$

where $\mathbf{X}_k = \begin{pmatrix} X_k^i & -X_k^{(i+1)*} \\ X_k^{i+1} & X_k^{i*} \end{pmatrix}$, $\mathbf{H}_{S-R} = \begin{pmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{pmatrix}$, and $\mathbf{N}_{S-R} = \begin{pmatrix} n_{11} & n_{12} \\ n_{21} & n_{22} \end{pmatrix}$. $\mathbf{X}_k$ is the STBC codewords; $\mathbf{H}_{S-R}$ is the coefficient of Rayleigh channel between SN and DN. $\mathbf{N}_{S-R}$ is noise signals, whose entries are the zero mean complex Gaussian variable with independent real and imaginary part of equal variance $(N_0/2)$ where N_0 is the noise power spectral density. In this paper, the code-cooperative scheme we put forward combines the characteristics of a Rayleigh fading channel, where $\mathbf{H}_{S-R}$ remains unchanged on a single codeword, but will varies independently on the transmission of the next codeword.

At the same time, the codeword $\mathbf{X}_k$ generated at the SN be broadcasted to the DN; the message sequence $\mathbf{y}_{S-D}$ transmitted to the DN in the first time slot is shown:

$$\mathbf{y}_{S-D} = \mathbf{H}_{S-D}\mathbf{X}_k + \mathbf{N}_{S-D}, \tag{22}$$

where the matrix $\mathbf{H}_{S-D}$ and $\mathbf{N}_{S-D}$ are denoted similarly as $\mathbf{H}_{S-R}$ and $\mathbf{N}_{S-R}$ in (21; 20). When message is transmitted to the DN, the received message sequence vector $\mathbf{y}_{S-D}$ passes over STBCs decoder to generate the signal sequence vector $\mathbf{Y}_1$ in the first time slot.

At the RN, the received message sequence vector passes over STBCs decoder and SC decoder of polar code to get the determine sequence bits $\tilde{\mathbf{I}}_{11}$. Then $\tilde{\mathbf{I}}_{11}$ will be further reencoded using $P_1(n_1,k_1,\alpha_1)$ to be $\bar{\mathbf{I}}_{11}$. The resulted codeword $\bar{\mathbf{I}}_{11}$ is sent to being BPSK modulation and get the signal $\bar{\mathbf{X}}_k$; then $\bar{\mathbf{X}}_k$ is sent to STBCs encoder, which generates space time block sequence bits $\bar{\mathbf{X}}_k^i$ and $\bar{\mathbf{X}}_k^{i+1}$, which are transmitted to the public DN shown by the dotted line in Figure 2. The received messages sequence vector $\mathbf{y}_{R-D}$ is shown:

$$\mathbf{y}_{R-D} = \mathbf{H}_{R-D}\bar{\mathbf{X}}_k + \mathbf{N}_{R-D}, \tag{23}$$

where the matrix $\mathbf{H}_{R-D}$ and $\mathbf{w}_{S-R}$ are denoted similarly as $\mathbf{H}_{S-R}$ and $\mathbf{N}_{S-R}$ in (21). The received message sequence vector $\mathbf{y}_{R-D}$ is sent to STBC decoder to result in the sequence vector $\mathbf{Y}_2 Y_2$ during the second time slot.

Finally, the overall received message sequence $\mathbf{Y}$ at the destination is generated by connecting the earlier received coded sequences, that is, $\mathbf{Y}_1$ and $\mathbf{Y}_2$ based on Plotkin structure, which could be depicted using (24):

$$\mathbf{Y} = [\hat{v}_2, \bar{v}_2] = [\mathbf{Y}_2, \mathbf{Y}_1]. \tag{24}$$

The decoding of the signals $\mathbf{Y}_1$ and $\mathbf{Y}_2$ are performed together rather than decoding each of the received signal separately. The message sequence $\mathbf{Y}$ is transmitted to SC decoder of polar code P, which estimates the original signal of bits $\hat{\mathbf{I}}_1$.

5 | SIMULATION RESULTS

In this chapter, the simulation results of the proposed scheme with MIMO scheme over fast Rayleigh fading channels is presented. Simultaneously, we also provide a sets of comparison simulations of their counterpart communication schemes. The signal modulation technique used in this article is binary phase shift keying (BPSK). At the same time, we provide a sets of comparison simulations with the scheme in literature [15]. The literature proposed a Plotkin-based cooperative polar-coded orthogonal frequency division multiplexing scheme on the basis of polar coded with Plotkin structure, and it also adopt the three user nodes cooperative technique. In our proposed scheme, neither the SN nor the RN owns a priori knowledge of their respective channels, and the DN own complete knowledge of the source-to-destination channel $\mathbf{H}_{S-D}$ and the relay-to-destination channel $\mathbf{H}_{R-D}$. The interactive channel between SN and RN is put to different SNR in different simulation. Moreover, the relay to source channel has been set to be the same with the source to destination.

The whole block length of the polar code is taken as 1024 bits, and the effective information bits is 512 bits and the parameters of P_1 is (512 256, α_1). In this cooperative scheme, the interactive channel of SN to RN is set to in ideal conditions or in 15 dB and 25 dB. The cooperative scheme with the best BER performance is the ideal interactive channel, 25 dB, 15 dB, and noncooperative scheme

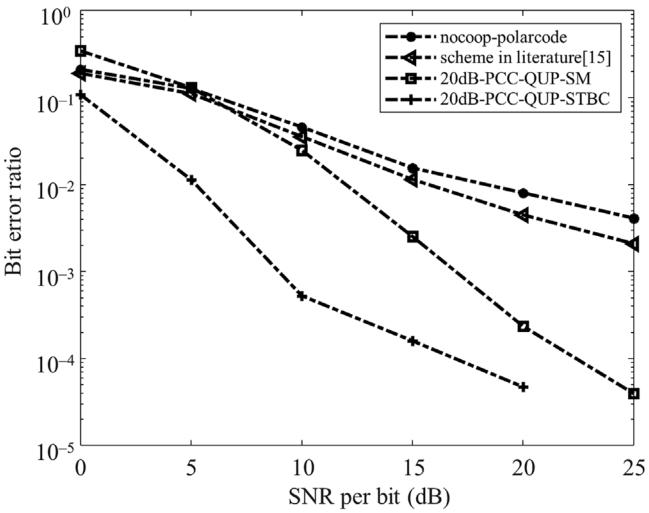

FIGURE 4 The BER performance of PCC-QUP with MIMO while the value of the interactive channel of source to relay node is 20 dB.

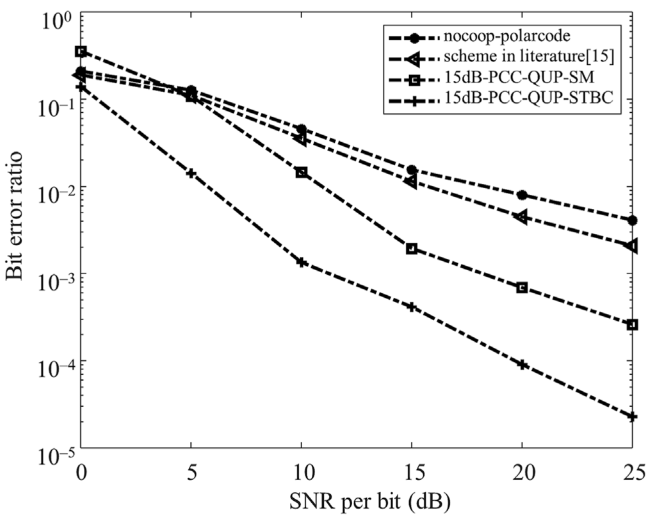

FIGURE 3 The BER performance of PCC-QUP with MIMO while the value of the interactive channel of source to relay node is 15 dB.

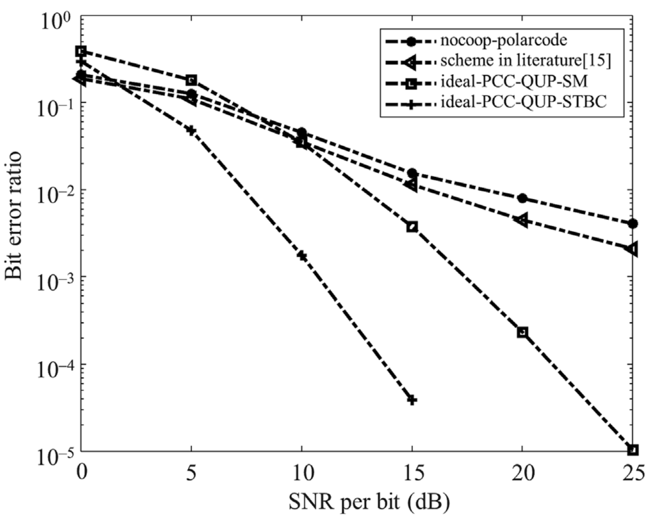

FIGURE 5 The BER performance of PCC-QUP with MIMO while the value of the interactive channel of source to relay node is ideal.

in order. The scheme in which interactive channel of SN to RN is ideal significantly better than the other schemes. The BER of proposed PCC-QUP scheme based on MIMO antennas in BPSK modulation is shown in Figures 3–5. At the same time, spatial modulation is a modulation technique that has attracted the attention of many researchers in recent years. We apply this PCC-QUP scheme into SM to forms a contrast scheme.

Let us to analyze the performance of the scheme in Figure 3, in which the value of SN to DN channel is set to 15 dB. It can be seen that the polar code improves the performance in the slow fading channel through the proposed cooperative Plotkin structure. The further proposed PCC-QUP scheme has a slight performance improvement. The BER performance of proposed PCC-QUP with STBC is outstanding than the corresponding scheme with SM. While the signal-to-noise ratio (SNR) of the channel from SN to DN is higher than 10 dB, the BER performance of the proposed PCC-QUP-STBC scheme has a significant improvement to the non-cooperation polar code scheme [15]. This shows that where the interactive channel is not very good, the error correction performance of the polar code interactive channel caused by QUP is not very weak, and it can change the cooperation ratio of the entire system information transmission.

The SNR of interactive channel in Figure 4 is 20 dB. The PCC-QUP scheme coded with SM still have obvious system benefits compared to the noncooperative polar code scheme. Simultaneously, the BER performance of proposed PCC-QUP scheme with STBC is also outstanding than the scheme with SM. When the SNR between SN and DN is 25 dB, the BER value come to zero. When the SNR of the channel between SN and DN is higher than 15 dB, the BER performance of the proposed scheme is improved by more than 5 dB compared with the scheme with SM, and it is improved by 10 dB compared to the non-cooperation polar code scheme.

This shows that when the interactive channel is good, the PCC-QUP-STBC scheme obviously changes the cooperation ratio of the entire system information transmission.

The interactive channel in Figure 5 is an ideal channel; the proposed coded-cooperative scheme based on quasi-uniformly punctured polar codes has obtained obvious system benefits. It can be found that while the SNR is higher than 5 dB, the PPC-QUP scheme with STBC scheme obviously achieves better BER performance than the PPC-QUP scheme with SM scheme. While the SNR of the channel of SN to DN is higher than 10 dB, the BER of the PPC-QUP scheme with STBC gets an improvement more than 3.5 dB compared to the PCC-QUP with SM. At the same time, the PCC-QUP with scheme proposed in this paper is improved by more than 5 dB compared to the polar code without cooperation.

6 | CONCLUSION

The communication system for 5G communication requires the performance of ultra-high-speed transmission, while the code-cooperation of polar code is a channel code method for high-speed transmission. However, there is currently little research on the coded-cooperation scheme based on polar code. The Plotkin structure based on AWGN channel proposed is no significant improvement in the performance of polar coded-cooperation schemes compared with slow fading channels. This article has conducted a comprehensive study on coded-cooperation based on polar codes from two aspects: codeword construction and performance optimization. Our proposed scheme is suitable for STBC schemes with arbitrary transmitting and receiving antennas. We propose a polar coded cooperative MIMO scheme on the basis of Plotkin structure and QUP method; simultaneously, the simulations results reveals that the cooperative scheme can improve the performance of 0.5 code rate polar code with length 1024 over Rayleigh fading channel.

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CONFLICT OF INTEREST STATEMENT

The authors declare that there are no conflicts of interest.

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