SIC Aided Physical-layer Network Coding for Multi-way Relay Channels

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***Abstract*—In this paper, we investigate the physical-layer network coding (PNC) scheme based on successive interference cancellation (SIC) in multi-way relay channels (MWRC). We consider a scenario where all users simultaneously transmit signals to the relay in the up-link stage while the relay broadcasts a coded message in the down-link stage. In order to extract the network codes from superimposed signals and guarantee a low decoding complexity, we propose a novel SIC scheme at the relay node to iteratively estimate the signals from all users. A Max-Min strategy is introduced as an optimal solution to power allocation among users to ensure accurate estimation in the SIC process. In addition, to further improve the system performance, an optimal strategy that decides the coding rule is developed by considering the error probability of the SIC process. Simulation results demonstrate the performance improvement of the proposed SIC aided PNC technique when used in conjunction with the optimal power allocation and coding rule in multi-way relay channels.**

I. Introduction

Physical layer network coding (PNC), which exploits the broadcast nature of wireless channels to improve the network throughput, has drawn much attention in recent years [1], [2]. In a classic half-duplex two way relay channel (TWRC) scenario, two end users intend to exchange information with the help of a relay. In contrast to the conventional network coding (NC) scheme which requires 2 time slots for up-link and 1 time slot for down-link transmissions [3], [4], PNC in TWRC only consumes 2 time slots in total. By exploiting the additive nature of electromagnetic (EM) waves at the physical layer, PNC allows the end users to send signals simultaneously to the relay using only 1 time slot. After extracting and decoding the superimposed user signals, the relay encodes the information into a NC signal and broadcasts it in a subsequent time slot. After reception of the broadcast NC signal, each user decodes the desired signal from the other user by employing its self-information. Compared with the conventional NC scheme, PNC leads to a 33% throughput improvement. Hence, PNC provides an efficient solution to meet the increasing need of wireless bandwidth and throughput from various applications envisaged for 5th generation (5G) wireless system such as streaming 4K video, machine-to-machine communications, online cloud sharing, etc. [5], [6].

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In order to take advantage of PNC for these applications, several studies have been carried out on TWRC PNC where specific issues such as the design of symbol mapping [7], [8] and the effect of time or phase synchronization [9], [10] are investigated. However, as a generalization of TWRC, multi-way relay channel (MWRC) for PNC, where multiple users share information through a single relay, has been less studied. Indeed, the superposition of multiple (i.e. $N > 2$) user signals at the relay increases the difficulty of extracting the NC signal due to the mutual interferences. Recently, two methods have been proposed in the literature to solve the problem of PNC in MWRC. In the first method [11], the MWRC network is decomposed into smaller building blocks, or *atoms*, over which existing TWRC techniques can be applied. Nonetheless, the approach requires at least $N-1$ time slots for up-link transmission in an N-way relay channel. In the second method [12], the constellation design for PNC in MWRC is formulated as a constrained optimization problem where the aim is to maximize the minimal distance among the set of NC symbols. The approach constructs the constellation of the transmitted signal to obtain the optimal error rate in decoding the superposed signals at the relay. However, the complexity of the design increases dramatically when the number of users and the modulation order become large.

In this paper, to address the aforementioned challenges, we investigate the use of successive interference cancellation (SIC) as a means to solve the PNC problem in MWRC. To further increase system throughput, we consider a scenario where all users simultaneously transmit signals to the relay in the up-link stage where only one time slot is needed. To extract the NCs from the superimposed signals at the relay while guaranteeing the low decoding complexity, we apply SIC to iteratively estimate the signals from all users. To ensure the accurate estimation in the SIC process, a Max-Min optimal strategy is proposed to allocate power among users. In addition, to further improve the system, an optimal strategy is also developed to decide the coding rule by considering the error probability of the NCs. Simulations over Rayleigh fading channels are conducted to demonstrate the effectiveness of the proposed MWRC-PNC based on SIC.

The paper is organized as follows: In Section II, the system model is introduced. In Section III, the SIC-based PNC scheme in MWRC is conveyed along with the proposed optimal power

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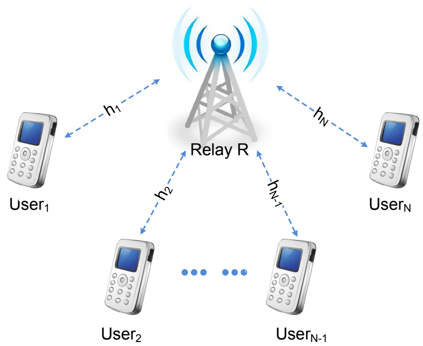


Fig. 1: System model of multi-way relay networks.

allocation and coding strategies. The simulation results are presented in Section IV, followed by a concluding statement in Section V.

II. System Model

In this section, we introduce the system model of MWRC PNC. The system setup and fundamental assumptions are presented in Section II-A. Then, the transmission procedure is explained in Section II-B.

A. System Setup

As shown in Fig. 1, we consider a half-duplex multi-way relay network where N users share information with each other through one relay (R). Users are equipped with single antenna and the relay is equipped with K ($K < N$) antennas to exploit the spatial diversity. We assume that there is no direct link among users and any information exchange between two users needs to go through the relay. BPSK modulation is applied by all nodes. As a conventional assumption adopted in most existing works on TWRC PNC [13], [14], perfect channel estimation and time synchronization are also available for any node in the network.

B. Transmission Procedures

The transmission has three steps, namely multiple access (MA, up-link) stage, relay detection and coding, and broadcast (BC, down-link) stage.

1) MA Stage: In the MA stage, all users simultaneously transmit signals to the relay. Note that the time slot consumed in this stage is 1. In this case, superimposed signals received at the relay are given by:

$$\boldsymbol{y} = \mathbf{HA}\boldsymbol{s} + \boldsymbol{n}_R, \tag{1}$$

where $\boldsymbol{y} \in \mathbb{C}^{K\times 1}$ is the received signal; $\boldsymbol{s} = [s_1, s_2, ..., s_N]^T \in \{-1, +1\}^{N\times 1}$ is the BPSK user symbol vector; $\mathbf{H} = [\boldsymbol{h}_1, \boldsymbol{h}_2, ..., \boldsymbol{h}_N] \in \mathbb{C}^{K\times N}$ represents the channel matrix and $\boldsymbol{h}_i \in \mathbb{C}^{K\times 1}$ is the channel vector between user i and the relay; $\mathbf{A} = diag(\sqrt{P_1}, \sqrt{P_2}, ..., \sqrt{P_N})$ is the diagonal power allocation matrix; $\boldsymbol{n}_R \in \mathbb{C}^{K\times 1}$ is the additive complex Gaussian noise vector.

2) Relay Detection and Network Coding: After MA stage, the relay generates $N-1$ valid network codes from $\boldsymbol{y}$ by mixing two selected user signals using modulo-2 sum "$\oplus$" based on a certain coding rule. Here, we denote the code as $\mathcal{S}_{ij} \triangleq s_i \oplus s_j$, $i, j \in \{1, 2, ..., N\}$, $i \neq j$. For example, a specific rule is explained as such: Signals of user 1 and user 2 are firstly extracted from $\boldsymbol{y}$ and then mixed as $\mathcal{S}_{12} = s_1 \oplus s_2$. The relay, in the same way, can encode other $N-2$ valid combinations to form a code set: $\{\mathcal{S}_{12}, \mathcal{S}_{23}, \mathcal{S}_{34}, ..., \mathcal{S}_{(N-1)(N)}\}$.

If s_i and s_j need to be coded, we apply the ML-detection on $\boldsymbol{s}$. The code $\mathcal{S}_{ij}$ is generated as:

$$\tilde{\boldsymbol{s}} = \arg \min_{\tilde{\boldsymbol{s}} \in \{-1,+1\}^N} ||\boldsymbol{y} - \mathbf{HA}\tilde{\boldsymbol{s}}||^2. \tag{2}$$

$$\mathcal{S}_{ij} = (\tilde{s}_i) \oplus (\tilde{s}_j), \ \ \tilde{s}_i, \tilde{s}_j \in \tilde{\boldsymbol{s}} \tag{3}$$

The computational cost increases with the increment of N. By examining the superimposed signal $\boldsymbol{y}$ at the relay, we find:

$$\boldsymbol{y} = \underbrace{\boldsymbol{h}_i \sqrt{P_i} s_i + \boldsymbol{h}_j \sqrt{P_j} s_j}_{\text{Part 1: lead to } s_i \oplus s_j} + \underbrace{(\sum_{m=1, m\neq i,j}^{N} \boldsymbol{h}_m \sqrt{P_m} s_m) + \boldsymbol{n}_R}_{\text{Part 2: interference+noise}}, \tag{4}$$

where Part 1 is used to generate the desired coded signal and Part 2 contains multi-user interferences and noises. As an alternative, we apply the ML-detection solely on s_i and s_j to reduce the complexity:

$$\{\tilde{s}_i, \tilde{s}_j\} = \arg \min_{\tilde{s}_i, \tilde{s}_j} ||\boldsymbol{y} - \boldsymbol{h}_i \sqrt{P_i} \tilde{s}_i - \boldsymbol{h}_j \sqrt{P_j} \tilde{s}_j||^2 \tag{5}$$

$$\mathcal{S}_{ij} = (\tilde{s}_i) \oplus (\tilde{s}_j) \tag{6}$$

However, the interference caused by multi-user signals severely degrades the performance when N increases. The proposed solution to this problem is discussed in Section III.

3) BC Stage: During this stage, the relay broadcasts one of $N-1$ network codes to users in each time slot according to a predetermined schedule. A total $N-1$ time slots are consumed. In a time slot t, if $\mathcal{S}_{ij}$ is broadcast, the signal received at user m is given by:

$$r_k^{(t)} = h_m \sqrt{P_r} \mathcal{S}_{ij} + n_m, \tag{7}$$

where P_r is the total transmitting power from relay; $h_m \in \mathbb{C}$ represents the down-link flat fading channel ; $n_m \in \mathbb{C}$ is the down-link additive complex Gaussian noise.

After $N-1$ time slots, user m receives all codes from the relay and uses self information s_k to obtain $\boldsymbol{s}$ based on the coding rule. For instance, by following the aforementioned rule, user 1 obtains s_2 by $\mathcal{S}_{12} \oplus s_1$ and uses s_2 to collect s_3 in the same manner. Continuing this successive process, user 1 can eventually obtain $\boldsymbol{s}$. The coding rule is designed to ensure all users' signals decode-able at any user. If any signal is not properly included, e.g., generating $\mathcal{S}_{35}$ instead of $\mathcal{S}_{34}$ in the above example, the combination is invalid since not all users' signals can be retrieved by using this rule. Then, the decoding chain breaks at the invalid combination.

III. The proposed method

In this section, we propose the SIC aided PNC in MWRC including the discussion on SIC process, the optimal power allocation, and the coding rule strategy.

A. Successive Interference Cancellation

As shown in Section II-B2, we can see that the ML-detection on superposed signals either increases the complexity or decreases the reliability in generating the network codes $\mathcal{S}_{ij}$ especially when N grows large. To solve this problem, we propose to use successive interference cancellation (SIC) to help the relay mitigate multi-user interferences.

Initially, as perfect channel estimations are assumed, the power allocation scheme for users is obtainable which will be explained in Section III-B. We label signals according to their received strength at the relay in a descending order as:

$$\left[||\boldsymbol{h}_1||\sqrt{P_1}, ||\boldsymbol{h}_2||\sqrt{P_2}, ..., ||\boldsymbol{h}_N||\sqrt{P_N}\right], \tag{8}$$

where $||\boldsymbol{h}_i||\sqrt{P_i} \geq ||\boldsymbol{h}_j||\sqrt{P_j}$, $\forall i < j$. We consider the following estimation and cancellation procedure:

Estimation: Given that $||\boldsymbol{h}_k||\sqrt{P_k}s_k$ is the strongest in $\boldsymbol{y}$, we denote $\boldsymbol{y}$ as $\boldsymbol{y}^{(k)}$. Estimate s_k from $\boldsymbol{y}^{(k)}$ using ML-detection:

$$\hat{s}_k = \arg\min_{s_k} ||\boldsymbol{y}^{(k)} - \boldsymbol{h}_k\sqrt{P_k}s_k||^2. \tag{9}$$

Cancellation: Using the estimated signal $\hat{s}_k$, we can remove the impact of s_k from $\boldsymbol{y}^{(k)}$ so as to generate $\boldsymbol{y}^{(k+1)}$ where s_{k+1} becomes the strongest signal. By subtracting $\hat{s}_k$, the result can be expressed as:

$$\boldsymbol{y}^{(k+1)} = \boldsymbol{y}^{(k)} - \boldsymbol{h}_k\sqrt{P_k}\hat{s}_k. \tag{10}$$

By far, the interference of previous signal s_k is eliminated when a perfect estimation on s_k is made. Similarly, the next strongest signal s_{k+1} is detected from $\boldsymbol{y}^{(k+1)}$ and its impact is also removed. In order to obtain all signals, we repeat above steps on the received signal $\boldsymbol{y}$ of each cycle until the weakest source signal s_N is obtained. By doing this, subsequently, an estimated signal vector, consisting of all user symbols, is given by:

$$\hat{\boldsymbol{s}} = [\hat{s}_1, \hat{s}_2, ..., \hat{s}_N] \tag{11}$$

B. Power Allocation Strategy

The estimation on s_k is important in the SIC. Otherwise, the error propagation occurs in the successive detection. A relatively reliable estimation of s_k can be achieved provided that the signal is stronger enough than the interference which consists of remaining $N-k$ signals plus noise. To ensure the reliability and optimize the performance, a power allocation strategy for users is applied.

Denote the user power as $\boldsymbol{P} = [P_1, P_2, ..., P_N]^T$. In each cycle of estimation and cancellation of $\boldsymbol{y}^{(k)}$, when perfect cancellation is applied, the SINR of s_k is given by:

$$\Gamma_k = \frac{P_k||\boldsymbol{h}_k||^2|s_k|^2}{\sum_{i>k}^N P_i||\boldsymbol{h}_i||^2|s_i|^2 + \sigma^2}, \tag{12}$$

where the denominator contains the uncanceled multi-user interference plus Gaussian noise variance σ^2. A set of all Γ_k is thus denoted as $\mathbb{S} = \{\Gamma_k | k = 1, 2, ..., N\}$. To reliably estimate s_k, Γ_k needs to be greater than a threshold γ:

$$\Gamma_k \geq \gamma, \ \forall k \in [1, N] \tag{13}$$

Since the network codes correlate to each other, an estimation error on s_k at the relay will result in propagated decoding failures at users. The decoding performance at users resembles the "leaky bucket effect". For a specific user end, one s_k with a high error probability dominates the overall error rate in decoding all user signals. The performance is improved only if the highest error probability is reduced. For this reason, we allocate the power $\boldsymbol{P}$ so as to maximize the minimum SINR in $\mathbb{S}$ subject to the total transmitting power constraint P:

$$\max_{\boldsymbol{P}} \ \min \mathbb{S} \tag{14}$$

$$s.t. \ \sum_{i=1}^N P_i = P_T \tag{15}$$

Since the channel information available, the relay can obtain values of allocated power. Before the transmission, each user receives a feedback of the value of allocated power from the relay and then transmits its signal. According to (12) and (13), since $|s_i| = 1$, the allocated power P_k satisfies the following inequality:

$$P_k||\boldsymbol{h}_k||^2 \geq \gamma(\sum_{i>k}^N P_i||\boldsymbol{h}_i||^2 + \sigma^2). \tag{16}$$

By solving (16), we obtain:

$$P_k||\boldsymbol{h}_k||^2 \geq \gamma(\gamma+1)^{N-k}\sigma^2 \tag{17}$$

Therefore, the problem is converted into maximizing the lowest boundary of Γ_k subject to (17):

$$\max_{\boldsymbol{P}} \ \gamma \tag{18}$$

$$s.t. \ P_k||\boldsymbol{h}_k||^2 \geq \gamma(\gamma+1)^{N-k}\sigma^2, \text{for } k = 1, 2, ..., N \tag{19}$$

$$\sum_{i=1}^N P_i = P_T \tag{20}$$

C. Coding Strategy

In order to improve the error probability of signals at each user, an optimal strategy which decides the coding rule at relay is required. We denote the strategy using a matrix $\boldsymbol{C}$ and define the operation as $\boldsymbol{\mathcal{S}} = \boldsymbol{C} \oplus \hat{\boldsymbol{s}}$. The modulo-2 operator "$\oplus$" here resembles the matrix and vector multiplication that it encodes two elements of signal vector $\hat{\boldsymbol{s}}$ according to the rule defined by $\boldsymbol{C}$.

The coding matrix $\boldsymbol{C}$ has two '1' s in each row and zeros for the rest, denoting that two specific users' signals are coded together. To ensure all users' signals decode-able in the down-link, the matrix $\boldsymbol{C}$ is designed to be full rank even if any column is removed. For a N-way relay network, matrix $\boldsymbol{C}$ can be generated in several structures corresponding to different coding rules. Let us take a 6-way relay network into consideration. One possible instance is given by:

$$\mathbf{C} = \begin{bmatrix} 1 & 1 & 0 & 0 & 0 & 0 \\ 1 & 0 & 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \quad (21)$$

In (21), any user's signal is coded with $\hat{s}_1$ such as, in the 2nd row, $\mathcal{S}_{13} = \hat{s}_1 \oplus \hat{s}_3$ represents that the user pair $< 1, 3 >$ is coded. For this instance, $\boldsymbol{C}$ includes 5 coding pairs where, for clarity, we define a set C for matrix $\boldsymbol{C}$ so as $C = \{< 1, 2 >, < 1, 3 >, < 1, 4 >, < 1, 5 >, < 1, 6 >\}$. As can be observed, s_1 is a critical node. An error on s_1 may cause numerous errors in generating $\boldsymbol{\mathcal{S}}$ which eventually downgrades the down-link performance due to the successive decoding process. Similar consequences also apply to any s_k for other possible rules.

Given user i and j with a coding rule C, one or several transition nodes, formed as user pairs, are contained in a link $\mathcal{L}(i, j)$. The relationship can be expressed as:

$$\mathcal{L}(i, j) = \{< i, a >, < a, b >, ..., < z, j >\}, \quad (22)$$

where if $\forall < \alpha, \beta > \in \mathcal{L}(i, j)$, $\exists < \alpha, \beta > \in C$.

Generally, the error probability of the received $\mathcal{S}_{\alpha\beta}$ at a user depends on the up-link (ul) and down-link (dl) error probability $p^{ul}_{<\alpha,\beta>}$, $p^{dl}_{<\alpha,\beta>}$. For the binary signaling at the relay, a correct code $\mathcal{S}_{\alpha\beta}$ is generated when two corrects or two wrongs are made on $\hat{s}_\alpha$ and $\hat{s}_\beta$. The up-link error probability of $s^{nc}_{\alpha\beta}$ with BPSK signaling can be determined as:

$$p^{ul}_{<\alpha,\beta>} = p_{e\alpha}(1 - p_{e\beta}) + p_{e\beta}(1 - p_{e\alpha}), \quad (23)$$

where $p_{e\alpha}$ and $p_{e\beta}$ represent the error probabilities of signal estimations on $\hat{s}_\alpha$ and $\hat{s}_\beta$ in the SIC process.

Let us assume that p_{ij} is the error probability of user i decoding the signal of user j. It is accumulated along $\mathcal{L}(i, j)$. Therefore, this is given by:

$$p_{ij} = 1 - \prod_{\forall<\alpha,\beta>\in\mathcal{L}(i,j)} (1 - p^{ul}_{<\alpha,\beta>})(1 - p^{dl}_{<\alpha,\beta>}). \quad (24)$$

For a given coding matrix $\boldsymbol{C}$, the average decoding error probability p^{avg}_e is calculated in terms of all possible p_{ij} for any user. Since the relay broadcasts $s^{nc}_{\alpha\beta}$ to all users under the same condition during the down-link, we can fairly assume that $p^{dl}_{<\alpha,\beta>}$ is identical to all users. This gives a symmetry property that $p_{ij} = p_{ji}$. Thus, p^{avg}_e can be expressed as:

$$p^{avg}_e = \frac{1}{N^2 - N} \sum_{i=1}^{N} \sum_{j=1, j\neq i}^{N} \left(1 - \prod_{\forall<\alpha,\beta>\in\mathcal{L}(i,j)} (1 - p^{ul}_{<\alpha,\beta>})(1 - p^{dl}_{<\alpha,\beta>}) \right) \quad (25)$$

$$= \frac{1}{N^2 - N} \sum_{i=1}^{N} \sum_{j=1, j\neq i}^{N} p_{ij} = \frac{2}{N(N-1)} \sum_{i=1}^{N} \sum_{j=i+1}^{N} p_{ij}. \quad (26)$$

We search and find out the optimal coding matrix $\boldsymbol{C}^*$ from all valid candidates to obtain the minimum p^{avg}_e:

$$\boldsymbol{C}^* = \arg\min_{\mathbf{C}} p^{avg}_e \quad (27)$$

D. Interference suppression and network coding using SIC:

According to $\boldsymbol{C}^*$ that decides the signal pair $< i, j >$, the undesired interference while extracting $\mathcal{S}_{ij}$ at the relay can be suppressed by using the results of SIC:

$$\boldsymbol{y}^{suppress}_{ij} = \boldsymbol{y} - \sum_{k=1, k\neq i,j}^{N} \boldsymbol{h}_k \sqrt{P_k} \hat{s}_k. \quad (28)$$

To this extent, the multi-user interference has been mitigated. The network coded signal, thereby, can be generated similarly as in a TWRC by using ML-detection from $\boldsymbol{y}^{suppress}_{i,j}$. The code thus is given by:

$$\{\tilde{s}_i, \tilde{s}_j\} = \arg\min_{\tilde{s}_i, \tilde{s}_j} ||\boldsymbol{y}^{suppress}_{ij} - \boldsymbol{h}_i \sqrt{P_i} \tilde{s}_i - \boldsymbol{h}_j \sqrt{P_j} \tilde{s}_j||^2 \quad (29)$$

$$\mathcal{S}_{ij} = (\tilde{s}_i) \oplus (\tilde{s}_j). \quad (30)$$

Eventually, the relay broadcasts a set of coded signal $\{\mathcal{S}_{ij} | < i, j > \in C^*\}$ to all users in the down-link stage.

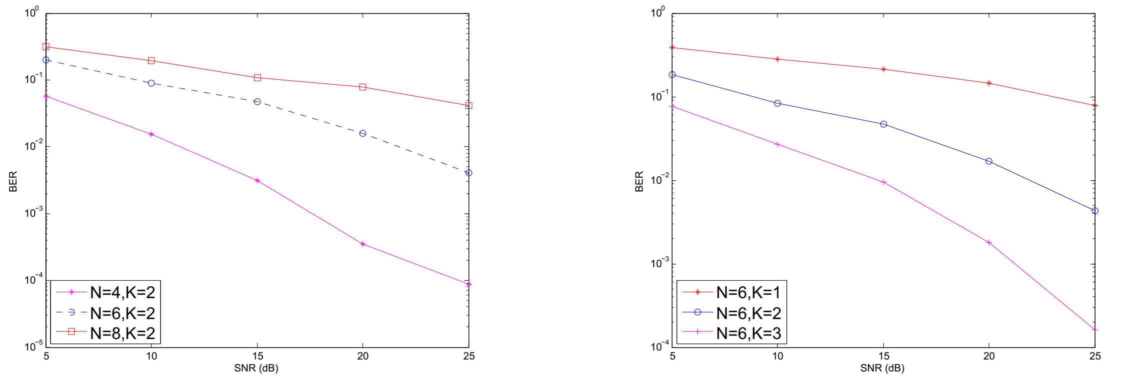
IV. Simulations

In this section, we present simulation results of the proposed multi-way relay PNC. For comparison purposes, the performance of the proposed system is considered under different parameters. The simulation environment settings are configured as follows. We use BPSK signaling where $s_k \in \{-1, +1\}$ are transmitted at both user and relay. The wireless channel is modeled as a Rayleigh fading channel where additive complex Gaussian noise $\mathbf{n} \sim \mathcal{CN}(0, 1)$ exists. Simulations are conducted under a network with $N \in \{4, 6, 8\}$ users and $K \in \{1, 2, 3\}$ relay antennas.

In Fig. 2a and Fig. 2b, we compare the up-link error performance with different N and K. At first, we increase N from 4 to 8 with a fixed $K = 2$. It can be observed that the error rate is inversely proportional to the number of users within the network. More user signals collide at the relay, worse the performance is due to the interference caused by multi-user signals. In the next, we investigate the spatial diversity provided by the multiple antenna of the relay with a fixed N. We notice that, with $N = 6$, the error rate is improved by more relay antennas but the improvement decreases while K increases (i.e., 12 dB improvement from $K = 1$ to 2 but only 7 dB from $K = 2$ to 3). The result demonstrates that the spatial diversity improves the performance of the system, but unlimited increment of relay antenna is not necessary especially when the device complexity is taken into consideration.

In Fig. 3, we study the effect of the optimal power allocation in a 4-way relay network with 2 antennas equipped at the relay. We implement the Max-Min optimal power allocation strategy while an equally distributed power scheme is conducted as the control group as well. As a result, a 6 dB improvement is observed between two schemes.

In Fig. 4, we further investigate the benefit of the optimal coding strategy by providing the comparison of the down-link system performance under 3 cases. In the fixed case, we keep a predetermined coding rule unchanged during the transmission process. In the worst case, we use the worst strategy that user



(a) Effects of different user quantity within network.

(b) Effects of different number of antennas at relay.

Fig. 2: Performance comparison with different user N and relay antennas K.

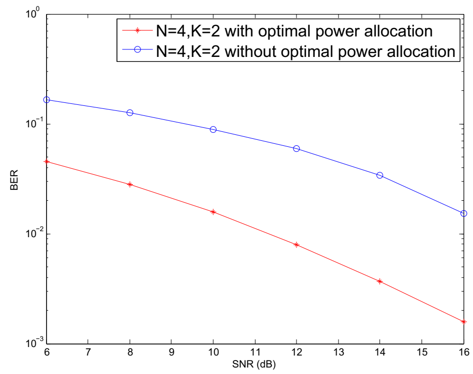


Fig. 3: Comparison of power allocation scheme.

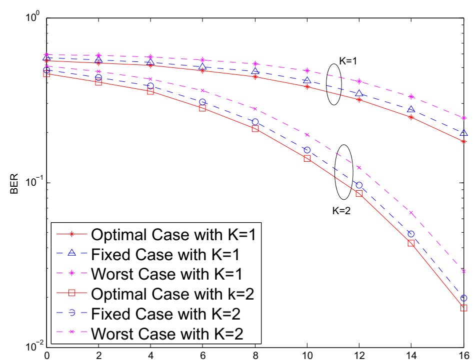


Fig. 4: System performance with different coding strategies.

signals are coded in the most insufficient manner. The optimal case is where we implement our proposed coding strategy. We provide the results under two different sets as $K = 1$ and $K = 2$. In each set, the worst case strategy gives an upper boundary of the achievable performance. As can be observed, our optimal coding strategy that targets to reduce the downlink error rate achieves the best performance comparing with the traditional fixed coding strategy.

V. Conclusions

In this paper, we have proposed a solution to the multi-way relay PNC problem by using successive interference cancellation. We used it to tackle the difficulty in extracting the network codes from the superimposed signals appearing in multiple sources. The key idea is to iteratively estimate all the user signals and take them as a support in canceling multi-user interference and generating network codes at relay. The Max-Min power allocation strategy is discussed to ensure the accuracy of the estimation in SIC while an optimal strategy is also implemented to further improve the system performance. Numerical results demonstrate the effectiveness of the proposed scheme while the optimal power allocation and coding strategy provides performance gains compared with the conventional methods.

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