Compress and Forward Cooperative Relay in Device-to-Device Communication with and without Coding Techniques

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***Abstract*— today, spectrum utilization problem is controlled by using Device to Device (D2D) communication systems. Also, cooperative relay networks play an important role in interference reduction during any communication system, so this paper addresses the Compress and Forward (CF) cooperative relay network using different code techniques with D2D communication in the cellular spectrums. Simulation results will illustrate that outage ratio is reduced by 9 dB using coded CF than using non decoded CF. Moreover, comparison between our proposed protocol and pervious protocols like Decode and Forward (DF) will be made, resulting in bit error rate reduction by 4.3 dB.**

Keywords*— *Cellular Users (CU); Device- to- Device (D2D); Cooperative relay networks; Wyner-Ziv coding.

I. Introduction

Cognitive Radio [1] and Device- to- Device (D2D) [2] systems are the latest applications in the world of communication that are used to beat the issue of the rise of modern and non-spectra application, so that these proposed systems exploit the licensed spectrum or cellular spectrum to make their own transmissions, and in return offer some services to the licensed users or cellular users (CU). In case of D2D system, one of D2D pairs acts as a relay to CU enable CU to send its data that suffering from noise and fading environment to the destination with maximum signal to noise ratio. Therefore, CU gives the D2D users the spectrum as a reward to allow D2D communication to be established.

Actually, D2D communication exploited in cellular system depends on D2D spectrum and in this case called inband D2D where it divided into underlay D2D [3] or overlay D2D [4], [5]. Outbound D2D is partitioned into two types; the first type is controlled [6] and the second type is autonomous [7].

The focal point of cooperative communication is the three relaying approaches. Three approaches depend on relay action, if relay decode, re-encode and forward the signal; this is the alleged Decode-and-Forward (DF) approach. If the relay essentially amplify the signal it gets and forwards it to the destination; this is the Amplify-and-Forward (AF) approach. Lastly, if the relay compresses the signal it gets, at that point encodes compacted form and sends it to the destination; this is termed Compress-and-Forward (CF). In this paper; D2D transmitter is considered as CF relay to the CU in the cellular spectrum. Moreover, comparison between this protocol and previous researches such as DF protocol will be made.

In the CF procedure, Wyner-Ziv coding was utilized by the relay in light of the fact that the destination utilizes the signal got specifically from the CU user as side information. A useful CF procedure with Wyner-Ziv coding was introduced in [8], for settled channels known to all terminals. However different commitments have disentangled the protocol by utilizing, rather than Wyner-Ziv coding, conventional CU user compression that does not consider the side information accessible at destination. In this work, we examine Wyner-Ziv coding on account of fading channels obscure to the transmitters and watch that, in specific conditions, the compression parameters limiting outage make Wyner-Ziv coding decrease to conventional CU user compression. The significance of this perception is that conventional CU user compression is less complex than Wyner-Ziv coding; that numerous CF schemes created in the paper have embraced traditional CU user compression, and that the circumstances for which traditional CU user compression is ideal can be fairly visit.

1.1 *Related Works*

The comparison between the proposed compress and forward relay and the recent related research work is illustrated in this subsection. The authors in [9] used the compress and forward relay protocol with the convolutional code (CC) in their system model at a fixed location, the author mentioned that his protocol reduce the outage probability by 3.6 dB. On the contrary of the previous protocol, the proposed CF relay utilizes the wyner ziv with the best relay location selection. So, the CU signal transmission with the lowest bit error rate (BER) is obtained relying on the selection of relay position. Moreover, the wyner ziv coding is more suitable for the CF relay as it required a small throughput to be established than using the CC code. Therefore, the overall system throughput is increased. Also, using the proposed CF relay as illustrated in simulation result section reduce the outage ratio by 9 dB. Reference [10] used decode and forward (DF) relay with the low density parity check code (LDPC) where, the CU signal is decoded with the LDPC code and retransmit to the destination. The author mentioned that his protocol reduce the bit error rate (BER) by 2 dB. However, the proposed CF relay protocol reduces the BER by 4.3 dB. CF relay first compress the CU signal using the wyner ziv coding so two different techniques (compress and coding) are applied on the obtained CU signal. Therefore, the transmission rate and the received CU SNR at the relay are increased so the BER at destination is decreased. The study in [11] used amplify and forward relay protocol (AF) where, the CU signal is amplified with amplification gain and retransmitted to the destination but the noise is also amplified and it is the main drawback of this protocol. Therefore, the BER of the CU signal is increased resulting in poor estimation of the CU signal at destination. The proposed CF relay relies on compressing the obtained CU signal so, the noise is decreased and BER is also decreased. Thus, our proposed relay protocol is more suitable for D2D transmission in the cellular spectrums.

1.2 Contributions

The contributions of this paper can be summarized as follows:

- Evolving a relay channel algorithm for D2D communication systems using CF relay
- Analyzing the execution of the proposed CF relay algorithm using Wyner-Ziv coding and without coding.
- Introducing some limitation on using Wyner-Ziv coding to obtain maximum rate with minimum BER.
- Exploring the ideal parameter for CF protocol to obtain minimum outage ratio for CU link.
- Studying the performance using previous protocol such as DF and compare it with our proposed protocol.
- Investigating SNR and outage probability with CF relay.
- Studying the best location of CF relay.

The paper is organized as follows: The system model is presented in section II. Section III seeks the cooperative approaches and section IV presents CF outage probability. Section V illustrates the simulation results and section VI concludes the paper.

II. SYSTEM MODEL

We consider a basic wireless relay network comprising of CU terminal, D2D transmitter that goes about as a relay to CU and a destination as in Fig.1. First the D2D transmitter (D2D 1) acts as a CF cooperative relay to the CU to insure that the communication between CU and its destination is done perfectly, therefore the CU allows the D2D pairs (transmitter and receiver) to communicate together using the CU spectrum without any distortion on the communication between the CU and the destination. The CF cooperative relay network is established as the follow; the CU user sequence X_s is transmitted and received by both the D2D transmitter or the CF relay and the destination as Y_{sr} signal using the relay channel and Y_{sd} signal using the direct channel between CU and destination, respectively:

$$\boldsymbol{Y_{sr} = h_{sr} X_s + Z_{sr}} \quad (1)$$

$$\boldsymbol{Y_{sd} = h_{sd} X_s + Z_{sd}} \quad (2)$$

The D2D transmitter (D2D 1) sends a sequence X_r to the destination

$$\mathbf{Y_{rd} = h_{rd} X_r + Z_{rd}} \quad (3)$$

Where, s, r, d indicate to the CU or sender, D2D transmitter or relay and destination sequences. We utilize a random code with complex Gaussian symbols with zero mean and variances P_s and P_r, respectively. We assume the code rates R_s and R_r. h_{ij}, Z_{ij} are the channel fading and the additive noise coefficients from terminal i to terminal j with i ∈ {s, r}, j ∈ {r, d}, where $\gamma_{sj} = |h_{sj}|^2 P_s$ and $\gamma_{rd} = |h_{rd}|^2 P_r$.

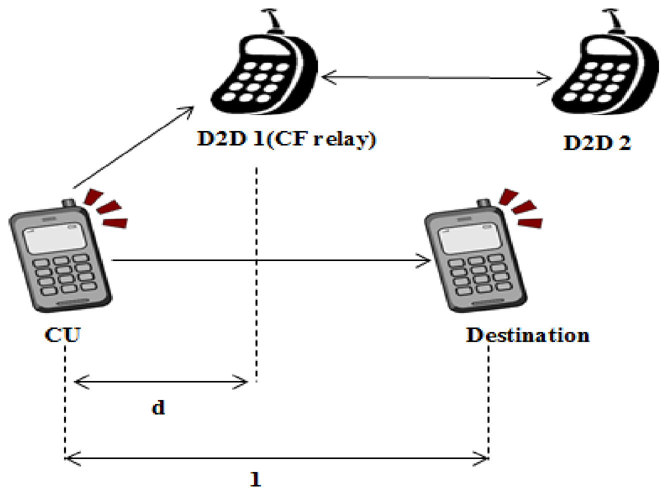

Fig.1 System Model

III. COOPERATIVE APPROACHES

Our cooperative approaches stretches out more than two slots; the CU user transmits in the first slot and the relay forwards in the second one. The processing at relay relies upon the nature of the signal got from the CU user. In this paper, we will compare our proposed relay channel approach with previous researches such as DF approach, so we will study the effect of using D2D transmitter as a DF relay first to ensure the progress resulting from using our proposed CF approach. Achievable rates with these approaches were determined in [8].

A. DF approach:

DF relay is used when the relay decodes X_s from Y_{sr}, and the code sends a sequence X_r with rate equal to $R_r = R_s$, where;

$$\boldsymbol{R_s \leq \log_2 (1 + \gamma_{sr})} \quad (4)$$

Both signals from the CU user and the relay are decoded by the destination under the constraint of the follows;

$$R \leq log_2\big((1 + \gamma_{sd})\,(1 + \gamma_{rd})\big) \tag{5}$$

Note that; R is achievable spectral efficiencies and we obviously have $R_s = R_r = 2R$.

B. CF approach:

If the decode process of CU signal at relay is failed, the CF approach is used with Wyner-Ziv coding, where the sequence $\mathbf{Y_{sr}}$ is compressed then the code word $\mathbf{X_r}$ is transmitted by the relay with the side information $\mathbf{Y_{sd}}$ to the destination. Destination utilizes $\mathbf{X_r}$ to estimate $\hat{Y}_{sr}$. To minimize the mean square error on the estimates $\hat{Y}_{sr}$, both the code rate $\mathbf{R_r}$ and the quantization noise variance $\mathbf{N_q}$ are controlled in the relay channel from CF relay or D2D1 to destination, these can be displayed as

$$\hat{Y}_{sr} = y_{sr} + Z_q \tag{6}$$

The event C of correct decoding resulting from decode sequence $\mathbf{X_r}$ using $\mathbf{Y_{rd}}$ at destination is written by

$$C: \quad R_r \leq log_2\,(1 + \gamma_{rd}) \tag{7}$$

Then, from $\mathbf{X_r}$ and $\mathbf{Y_{sd}}$ the receiver tries to acquire $\hat{Y}_{sr}$; the event D of correct decompression is done by,

$$D: \quad R_r \geq log_2\left(1 + \frac{1+\frac{y_{sr}}{1+y_{sd}}}{N_q}\right) \tag{8}$$

Compression restrictions to obtain an appropriate $\mathbf{R_r}$ in (8) for different $\mathbf{N_q}$ in the cases where γ_{sd} would be, respectively, very large or equal to 0 must be as the follow;

$$\log_2\left(1+\frac{1}{N_q}\right) \leq R_r \leq \log_2\left(1+\frac{1+y_{sr}}{N_q}\right) \tag{9}$$

In the case that both C and D satisfy, the achievable cooperative transmission spectral efficiencies are fulfilling,

$$R \leq \frac{1}{2}\log_2\left(1 + y_{sd} + \frac{y_{sr}}{1+N_q}\right) \triangleq I_{CF} \tag{10}$$

If the direct channel signal from CU to destination only is used and the other relay channel signal from relay to destination is unutilized; the achievable rates are then restricted to

$$R \leq \frac{1}{2}\log_2(1 + y_{sd}) \triangleq I_{sd}. \tag{11}$$

IV. CF OUTAGE PROBABILITY

In the CF case, an outage occasion happen when either (10) or (11) are not fulfilled; contingent upon whether the occasions C and D happen. All the more correctly, if the decoding falls flat ($\bar{C}$), or on the off chance that it succeeds yet the decompression fizzles (C, $\bar{D}$), the fitting limitations on the spectral efficiency is (11); if both decoding and decompression succeed (C, D) at that point (10) is the correct constraint. This yields the accompanying decomposition of the outage probability for a spectral efficiency **R** and given γ_{sr}:

$$\begin{aligned} P_{out}(R|\, y_{sr}) = {} & P(R > I_{CF}\,|C,D,\gamma_{sr}) \cdot P(D|C,\gamma_{sr})P(C|\gamma_{sr}) \\ & + P(R > I_{sd}) \cdot P(C^{-}|\gamma_{sr}) \\ & + P(D^{-}|C,\gamma_{sr})\,P(C|\,\gamma_{sr}) \end{aligned} \tag{12}$$

The probabilities clarifying in (12) are:

- The likelihood of not fulfilling the rate constraint (10), shown that the destination has possessed the capacity to decode and decompress the signal from the relay:

$$P(R > I_{CF}\,|C,D,\gamma_{sr}) = 1 - exp\left(\frac{-1}{\sigma_{sd}^2}\left(2^{2R} - 1 - \frac{y_{sr}}{1+N_q}\right)\right) \tag{13}$$

  This is legitimate just if $Nq > \frac{y_{sr}}{2^{2R}-1} - 1$; this imbalance dependably holds since we utilize CF just when the relay can't decode, in this way when the right-hand individual from the disparity is negative.

- The probability of not satisfying the rate constraint (11):

$$P(R > I_{sd}) = 1\text{-}\, exp\left(-\frac{2^{2R}-1}{\sigma_{sd}^2}\right) \tag{14}$$

- The probability of successfully decoding the signal from the relay:

$$P(C|\,\gamma_{sr}) = exp\left(-\frac{2^{2R_r}-1}{\sigma_{sd}^2}\right) \tag{15}$$

- And finally the probability of successfully decompressing the signal from the relay:

$$P(D|C,\gamma_{sr}) = exp\left(\frac{-1}{\sigma_{sd}^2}\left(\frac{y_{sr}}{(2^{R_r}-1)N_{q-1}} - 1\right)\right) \tag{16}$$

  which is valid for pairs (R_r, N_q) satisfying (9).

V. SIMULATION RESULTE

In this Section, many MATLAB programs are made to present some proposed compress and forward relay performance in presence of channel problem such as noise, fading and multipath. The relay network is depicted in Fig.1where; every one of the three terminals is arranged. The relay is at a separation **d** from the CU user and the separation between the CU user and the destination is standardized to **1**. Path loss between the terminals decides the power levels at the receivers. With a path loss exponent chosen equal to $\boldsymbol{\alpha = 3.5}$ we have $\boldsymbol{\sigma_{sd}^2 = P_s}$, $\boldsymbol{\sigma_{sr}^2 = {P_s}/{d^{\alpha}}}$ and $\boldsymbol{\sigma_{rd}^2 = {P_r}/{(1-d)^{\alpha}}}$.

Fig.2 explains the improvement of outage ratio that achieved by using wyner- ziv coding rather than using compress technique only in CF protocol, that is because traditional CF compress all received message reached to relay and sends it to destination, resulting to incorrect message with high reflectance of noise and other interferences send to destination. Outage ratio is reduced by sing CF with wyner- ziv coding 9 dB rather than using CF protocol only.

Fig.3 demonstrates the comparison between SNR performance of both the proposed CF relay and DF relay, at SNR equal to 25 dB, BER will be reduced by 4.3 dB than using DF relay that is because using the CF relay resulting in increasing rate and received SNR at the relay is increased so BER will be decreased.

Fig.4 shows that the utilization of wyner-ziv coding diminishes when the relay draws near to the destination; this is on the grounds that the rate $\boldsymbol{R_r}$ can be picked large since the relay to destination channel is relied upon to be solid. The accessibility of a high transmission rate $\boldsymbol{R_r}$ makes wyner-ziv coding less appealing. Therefore the best location of the CF relay is in the middle distance between the CU and destination in cellular spectrum that is mean that the D2D transmitter must not located nearest from neither CU nor destination, as BER is reduced by 15 dB.

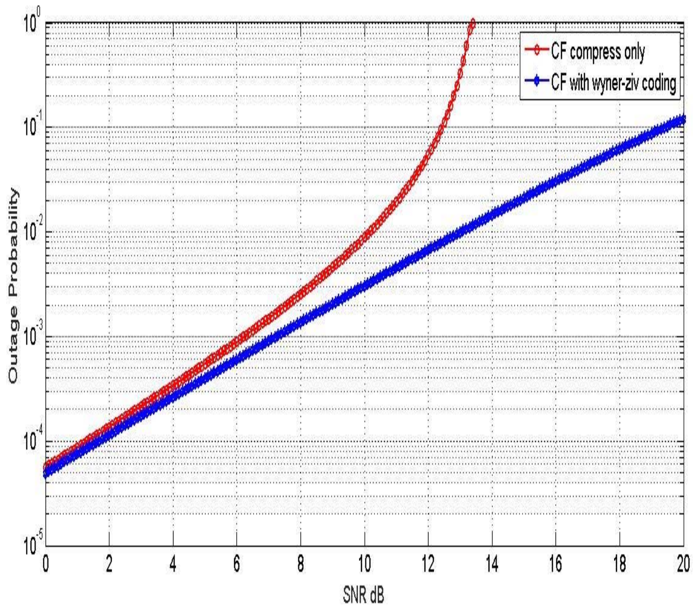

Fig.2 Outage performance of the proposed CF relay protocol

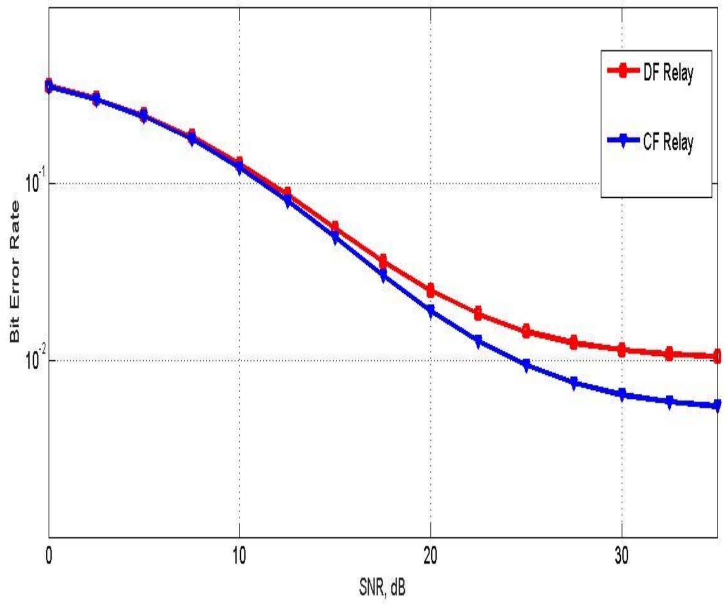

Fig.3 SNR performance of the proposed CF relay

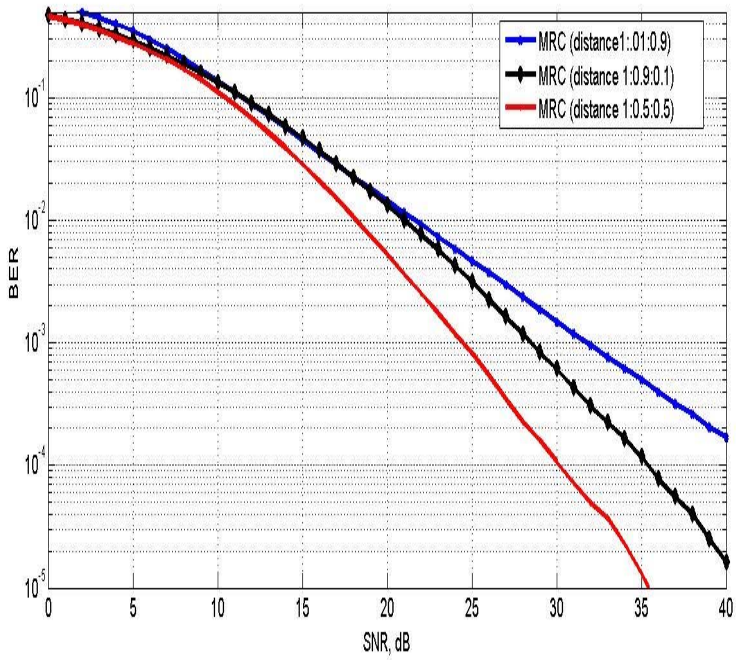

Fig.4 Best location of CF relay

VI. CONCULISION

This paper proposes to use one of the D2D pairs as a compress and forward (CF) relay to the cellular user. CF protocol with and without wyner-ziv coding is introduced. Moreover, we address the optimization of the wyner-ziv coding parameters of the CF protocol, and show that using wyner-ziv CF protocol will reduce the BER than using previous protocols such as decode and forward (DF) protocol. System model and its optimal parameter to reach minimum outage ratio are explained in detail. Moreover, simulation results are made to ensure our analysis. The electronic relay consists of hybrid relay protocols will be made in the future work.

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