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Distributed differential beamforming and power allocation for cooperative communication networks

Samer Alabed, Issam Maaz, Mohammad Al-Rabayah
College of Engineering and Technology, American University of the Middle East, Kuwait

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ABSTRACT

Many coherent cooperative diversity techniques for wireless relay networks have recently been suggested to improve the overall system performance in terms of the achievable data rate or bit error rate (BER) with low decoding complexity and delay. However, these techniques require channel state information (CSI) at the transmitter side, at the receiver side, or at both sides. Therefore, due to the overhead associated with estimating CSI, distributed differential space-time coding techniques have been suggested to overcome this overhead by detecting the information symbols without requiring any (CSI) at any transmitting or receiving antenna. However, the latter techniques suffer from low performance in terms of BER as well as high latency and decoding complexity. In this paper, a distributed differential beamforming technique with power allocation is proposed to overcome all drawbacks associated with the later techniques without needing CSI at any antenna and to be used for cooperative communication networks. We prove through our simulation results which is based on error probability that the proposed technique outperforms the conventional technique with comparably low decoding complexity and latency.

Corresponding Author:

Samer Alabed,
Department of Electrical Engineering,
College of Engineering and Technology,
American University of the Middle East,
P.O. Box: 220 Dasman, 15453, Kuwait
Email: Samer.Al-abed@aum.edu.kw

1. INTRODUCTION

Differential modulation has recently received considerable interest as it offers diversity and coding gain without the need for channel estimation [1-8]. Relaying techniques for wireless communication systems have been studied extensively in the last decade [9-16]. They have proposed many promising features such as high data rates, and better capacity. However, with the need for higher data rate and better performance in the current wireless communication systems, investigating new channel coding techniques is essential for such needs. Many methods have been proposed in order to increase the data rate such as massive multiple-input multiple-output (MIMO) techniques [17-28], carrier aggregation and different encoding techniques. However, these techniques increase the complexity of the communication systems.

Communications over channels with fading nature may demand channel state information (CSI) at the transmitter, at the relay node or at the receiver according to the used technology [9-12]. Some techniques such as distributed beamforming assumes a perfect CSI at all nodes, which is considered unrealistic [17, 18]. Techniques like distributed space-time coding (DSTC) consider a perfect or semi perfect CSI at the receiver [4-8] while other techniques such as time reversal (TR) consider a perfect CSI at transmitter side [27]. The need for CSI leads to a significant increase in the system complexity. This increase in system complexity motivates us to investigate different techniques that were proposed to overcome those problems such as differential modulation [1-8, 29]. Differential coding processes memory in the transmitted data where this memory is utilized at the receiver side in order to decode the transmitted data without the need of the channel coefficient. This technique is very important for fast fading channels in order to avoid the need of channel estimation at the receiver and to increase the data rate. Recently, many techniques such as differential distributed space-time coding (Diff-DSTC) strategies [4-8] have been proposed without the need of CSI to receive the transmitted data. However, the system performance of Diff-DSTC is considered low in terms of bit error rate with a high decoding complexity. Differential techniques with beamforming have been proposed to receive transmitted data by combining the differential diversity strategy and beamforming strategy [1-3]. This technique does not require any CSI at the receiver or at the transmitter, however it needs (R+ 1) time slots to transmit each symbol where R is the number of relay nodes. As a result, the spectral efficiency will decrease with the increase of the number of used relays. Finally, several relaying protocols have been proposed [4-8, 26] for wireless relay networks such as amplify-and-forward (AF) and decode-and-forward (DF) protocol.

In this paper, we propose a novel strategy based on beam-forming and differential coding with power allocation scheme to be used for two-way wireless relay networks that improves the overall system performance in terms of bit error rate (BER) with low decoding complexity and low latency without requiring CSI at any transmitting or receiving node.

2. RESEARCH METHOD

Differential encoding techniques based on the amplify-and-forward protocol are well known for their poor BER performance, high decoding complexity, and long latency. On the other hand, differential beamforming techniques provide higher BER performance, optimal decoding complexity, and low latency [1-4]. This article combines the differential diversity and the distributed beamforming techniques using either the AF or the DF protocol, as well as employs a power allocation strategy and M-ary phase shift keying (M-PSK) constellations to provide an improved BER performance, low decoding complexity, and optimal delay without the need for any CSI.

2.1. System model

As the differential beamforming technique does not perform any channel estimation at all nodes, then the knowledge of any CSI is not required [1, 6]. Furthermore, differential beamforming employs either the AF and DF protocols using four-phase modulation schemes to achieve a high BER performance, small end-to-end delay, and low decoding complexity through adjusting the phase of the received signal at the relay-nodes, and by forming a beam steered toward the receiving nodes [1-3, 17, 18]. Our system model is shown in Figure 1 that is composed of $r+2$ half duplex wireless network nodes, including two terminal nodes τ_1 and τ_2 who are willing to exchange signals through r relay nodes located between them. Those relay nodes are equipped with a single antenna and are working in the half-duplex mode. It is assumed here that the channel remains constant for the duration of a frame and it may vary independently from one frame to the other. Furthermore, the channels are assumed to be a Rayleigh fading channel with zero mean and σ^2 variance, i.e., $f_r \sim \left(N\left(0,\sigma_{f_r}^2\right)\right.$ and $g_r \sim \left(N\left(0,\sigma_{g_r}^2\right)\right.$. Moreover, we denote the channel from τ_1 to the k^{th} relay node as $f_r\,(k)$, and the channel from τ_2 to the k^{th} relay node as $g_r\,(k)$. Finally, it is assumed that the relay- nodes are perfectly synchronized and that CSI are not required to τ_1 and τ_2, and that all nodes have limited average transmit powers $[P_{\tau_1}, P_{\tau_2}, P_{R_1}, \dots P_{R_r}]$.The two terminals τ_1 and τ_2 are transmitting the differentially encoded scalars $x_{\tau_1}(k)$ *and* $x_{\tau_2}(k)$ respectively, then a transmitted signal by terminals τ_1 and τ_2 can be expressed as:

$$x_{\tau_t}(k) = x_{\tau_t}(k-1)s_{\tau_t}(k) \tag{1}$$

where t =1, 2, $s_{\tau_1}(k)$ and $s_{\tau_2}(k)$ are the data symbols of the k^{th} block. Note here that the initial symbols in the first transmission round, $x_{\tau_1}(0) = x_{\tau_2}(0) = 1$ can be used as a reference at the receiver, and that $E\left\{\left|x_{\tau_1}(k)\right|^2\right\}$= $E\left\{\left|x_{\tau_1}(k)\right|^2\right\} = 1$ and $\left|x_{\tau_t}(k)\right| = \left|s_{\tau_t}(k)\right|$. Now, assuming the use of M-PSK constellation denoted by a set S_{τ_t} in respect to τ_t, hence $s_{\tau_t}(k) \epsilon\, S_{\tau_t}$. Then at the first phase, the r^{th} relay R_r receives the following signal:

$$y_{R1,r}(k) = \sqrt{P_{\tau 1}} f_r(k) x_{\tau 1}(k) + \eta_{R1,r}(k) \tag{2}$$

Similarly, the r^{th} relay R_r in the second phase receives the below signal:

$$y_{R2,r}(k) = \sqrt{P_{\tau 2}}g_r(k)x_{\tau 2}(k) + \eta_{R2,r}(k) \quad (3)$$

where $\eta_{R1,r}(k)$ and $\eta_{R2,r}(k)$ denotes the independent and identically distributed additive white Gaussian noise (AWGN), and $\eta_{R2,r}(k) \sim CN\left(0, \sigma_{g_r}^2 I_T\right)$. At this point, each relay-node will receive the transmission of both terminals τ_1 and τ_2 , adjust their phases, amplifies their amplitudes, and forwards them back to the intended terminals. Therefore, in the third and fourth phase, the r^{th} relay transmits the following signals:

$$x_{R1,r}(k) = \beta_1 y_{R1,r}(k)e^{j\theta_{R1,r}(k)} \quad (4)$$

$$x_{R2,r}(k) = \beta_2 y_{R2,r}(k)e^{j\theta_{R2,r}(k)} \quad (5)$$

where β_1 and β_2 are two scaling factors.

Note here that the optimal value of $\theta_{Rt,r}(k), t = 1, 2, r = 1,2,3, .., R$, can be found using coherent superposition of the received signals at each relay-node, such that the overall signal to noise ratio (SNR) at both terminals is maximized, and can be given as:

$$\theta_{R1,r}^{opt}(k) = -\left(\measuredangle y_{R1,r}(k-1) + \measuredangle y_{R2,r}(k)\right) + c \quad (6)$$

$$\theta_{R2,r}^{opt}(k) = -\left(\measuredangle y_{R1,r}(k) + \measuredangle y_{R2,r}(k-1)\right) + c \quad (7)$$

where c is an arbitrary constant. Now, let us assume that $P_{R1} = P_{R2} = \cdots = P_{R_r} = P_R$. Then, the overall SNR at terminal τ_2 can be given as

$$\gamma_{\tau_2} = \frac{\frac{P_{\tau_1}P_R}{P_{\tau_1}+1}E\left\{\left|\sum_{r=1}^{R} f_r(k)g_r(k)e^{j\theta_{R1,r}(k)}\right|^2\right\}}{E\left\{\left|\eta+\eta_{\tau_2}(k)\right|^2\right\}} \quad (8)$$

where $(\eta + \eta_{\tau_2}(k))$ denotes the noise at the second terminal. Using Cauchy-Schwarz inequality theorem, we get:

$$\left|\sum_{r=1}^{R} f_r(k)g_r(k)e^{j\theta_{R1,r}}\right|^2 \leq \left|\sum_{r=1}^{R} f_r(k)g_r(k)\right|^2 \quad (9)$$

Note here that (9) holds with equality when the phase shift $\theta_{R1,r}\ is\ -\left(\measuredangle_{f_r(k)} + \measuredangle_{g_r(k)}\right) + c\ ,\forall r.$

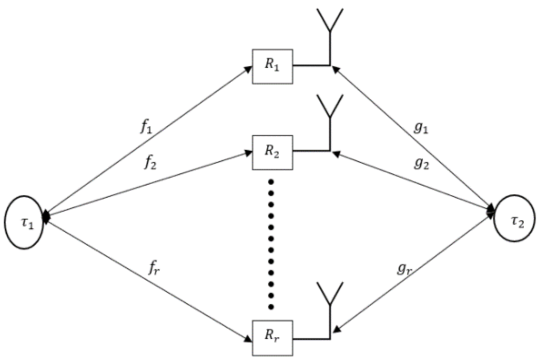

Figure 1. Tow-ways wireless relay network (TWRN) with multiple single-antenna relays

Using our previous assumption that there is no channel state information (CSI) available at any node, and assuming $g_r(k) = g_r(k-1), f_r(k) = f_r(k-1)$ and under the ideal noise free scenario where $\eta_{Rt,r}(k-1) = 0,\ t = 1,2, r = 1,2,3, ..., R$. Thus, (6) and (7) can now be rewritten as:

$$\theta_{R1,r}(k) = -\left(\measuredangle f_r(k) + \measuredangle g_r(k)\right) - \left(\measuredangle x_{\tau_1}(k-1) + \measuredangle x_{\tau_2}(k)\right) \quad (10)$$

$$\theta_{R2,r}(k) = -\left(\measuredangle f_r(k) + \measuredangle g_r(k)\right) - \left(\measuredangle x_{\tau_1}(k) + \measuredangle x_{\tau_2}(k-1)\right) \quad (11)$$

It can be noted here that in (10) and (11), the two phase terms $-\left(\measuredangle x_{\tau_1}(k-1) + \measuredangle x_{\tau_2}(k-1)\right)$ and $-\left(\measuredangle x_{\tau_1}(k-1) + \measuredangle x_{\tau_2}(k-1)\right)$ are constants. Then, the signals received at the terminals τ_1 *and* τ_2 in the third and fourth time slot of the k^{th} transmission block, are given by:

$$y_{\tau_1}(k) = \sum_{r=1}^{R} f_r(k) x_{R2,r}(k) + \eta_{\tau_1}(k) \quad (12)$$

$$y_{\tau_2}(k) = \sum_{r=1}^{R} g_r(k) x_{R1,r}(k) + \eta_{\tau_2}(k) \quad (13)$$

where $\eta_{\tau_1}(k)$ and $\eta_{\tau_2}(k)$ are the noise signals at the two terminals τ_1 *and* τ_2 in respect to the k^{th} block. Given the high SNR in (12) and (13), those two equations can be rewritten as:

$$y_{\tau_1}(k) \cong \sum_{r=1}^{R} \sqrt{\frac{P_{Rr}}{P_{\tau_2}+1}} |f_r(k)||g_r(k)| e^{\left(-jx_{\tau_1}(k)\right)} s_{\tau_2}(k) + w_{\tau_1} \quad (14)$$

$$y_{\tau_2}(k) \cong \sum_{r=1}^{R} \sqrt{\frac{P_{Rr}}{P_{\tau_2}+1}} |f_r(k)||g_r(k)| e^{\left(-jx_{\tau_2}(k)\right)} s_{\tau_1}(k) + w_{\tau_2} \quad (15)$$

where

$$w_{\tau_1} = \sum_{r=1}^{R} \sqrt{\frac{P_{Rr}}{P_{\tau_2}+1}} (f_r(k) e^{\left(j\theta_{R2,r}(k)\right)}) + \eta_{\tau_1} \quad (16)$$

$$w_{\tau_2} = \sum_{r=1}^{R} \sqrt{\frac{P_{Rr}}{P_{\tau_1}+1}} (g_r(k) e^{\left(j\theta_{R1,r}(k)\right)}) + \eta_{\tau_2} \quad (17)$$

Now, to retrieve the transmitted signal at the first terminal τ_1, the following decoder can be performed:

$$\arg\min_{s(k)} \left\| \frac{y_{\tau_1}(k)}{e^{\left(-j\measuredangle x_{\tau_1}(k)\right)}} - \left| \frac{y_{\tau_1}(k-1)}{e^{\left(-j\measuredangle x_{\tau_1}(k-1)\right)}} \right| s(k) \right\|^2 \quad (18)$$

Similarly, the following decoder can be performed to recover the transmitted signal at the second terminal τ_2:

$$\arg\min_{s(k)} \left\| \frac{y_{\tau_2}(k)}{e^{\left(-j\measuredangle x_{\tau_2}(k)\right)}} - \left| \frac{y_{\tau_2}(k-1)}{e^{\left(-j\measuredangle x_{\tau_2}(k-1)\right)}} \right| s(k) \right\|^2 \quad (19)$$

Considering $\left[x_{\tau_t}(k)\right]_r$ *and* $\left[\tilde{s}_{\tau_t}(k)\right]_r$ and using M-PSK constellations of the set of $\tilde{s}_{\tau_t}(k)$ can be found corresponding to the receiving terminals τ_t, where $\left[x_{\tau_t}(k)\right]_r \in S_t$ *and* $\left[\tilde{s}_{\tau_t}(k)\right]_r \in S_t$.

2.2. Differential beamforming using the DF protocol

From (2) and (3) the relay-nodes can decode $\tilde{s}_{\tau_1}(k)$ and $\tilde{s}_{\tau_2}(k)$. In order to recover the transmitted signals at the relay-nodes, the following decoder can be performed:

$$\tilde{s}_{\tau_1}(k) = arg \min_{s_{\tau_1}(k)} \left\| y_{R,1}(k) - \left|y_{R,1}(k-1)\right| s_{\tau_1}(k) \right\|^2 \quad (20)$$

$$\tilde{s}_{\tau_2}(k) = arg \min_{s_{\tau_2}(k)} \left\| y_{R,2}(k) - \left|y_{R,2}(k-1)\right| s_{\tau_2}(k) \right\|^2 \quad (21)$$

Then, the r^{th} relay-node transmits the following signal to both terminals during the third and fourth time slots:

$$t_{R1,r}(k) = \beta_1 \tilde{s}_{\tau_1}(k) e^{-j\measuredangle\left(y_{R,2}(k)\right)} = \beta_1 \tilde{s}_{\tau_1}(k) \frac{\left(y_{R,2}(k)\right)^*}{|y_{R,2}(k)|} = \beta_1 \tilde{s}_{\tau_1}(k)\, e^{-j\measuredangle g_r(k)} e^{-j\measuredangle x_{\tau_2}(k)} \quad (22)$$

$$t_{R2,r}(k) = \beta_1 \tilde{s}_{\tau_2}(k)\, e^{-j\measuredangle f_r(k)} e^{-j\measuredangle x_{\tau_1}(k)} \quad (23)$$

Meanwhile, in the third and fourth time slot of the k^{th} trans3mission block, the received signals at terminals τ_1 and τ_2 can be expressed as:

$$y_{\tau_1}(k) = \sum_{r=1}^{R} f_r(k) t_{R2,r}(k) + \eta_{\tau_1}(k) \quad (24)$$

$$y_{\tau_2}(k) = \sum_{r=1}^{R} g_r(k) t_{R1,r}(k) + \eta_{\tau_2}(k) \quad (25)$$

where $\eta_{\tau_1}(k) and\, \eta_{\tau_2}(k)$ are the noise signals at the two terminals τ_1 and τ_2 in respect to k^{th} block. Assuming high SNR, then (24) and (25) can be expressed as:

$$y_{\tau_1}(k) \cong \sum_{r=1}^{R} \sqrt{\frac{P_{Rr}}{P_{\tau_2}+1}} |f_r(k)| e^{\left(-jx_{\tau_1}(k)\right)} s_{\tau_2}(k) + w_{\tau_1} \quad (26)$$

$$y_{\tau_2}(k) \cong \sum_{r=1}^{R} \sqrt{\frac{P_{Rr}}{P_{\tau_1}+1}} |g_r(k)| e^{\left(-jx_{\tau_2}(k)\right)} s_{\tau_1}(k) + w_{\tau_2} \quad (27)$$

where,

$$w_{\tau_1} = \sum_{r=1}^{R} \sqrt{\frac{P_{Rr}}{P_{\tau_2}+1}} \left(f_r(k) e^{\left(j\theta_{\mathrm{R2,r}}(k)\right)}\right) + \eta_{\tau_1} \quad (28)$$

$$w_{\tau_2} = \sum_{r=1}^{R} \sqrt{\frac{P_{Rr}}{P_{\tau_1}+1}} \left(g_r(k) e^{\left(j\theta_{\mathrm{R1,r}}(k)\right)}\right) + \eta_{\tau_2} \quad (29)$$

Finally, to retrieve the transmitted signal at the first terminal τ_1, the following decoder can be performed:

$$\arg\min_{\tilde{s}(k)} \left\| \frac{y_{\tau_1}(k)}{e^{\left(-j\measuredangle x_{\tau_1}(k)\right)}} - \left| \frac{y_{\tau_1}(k-1)}{e^{\left(-j\measuredangle x_{\tau_1}(k-1)\right)}} \right| \tilde{s}(k) \right\|^2 \quad (30)$$

Similarly, the following decoder can be performed to recover the transmitted signal at the second terminal τ_2:

$$\arg\min_{\tilde{s}(k)} \left\| \frac{y_{\tau_2}(k)}{e^{\left(-j\measuredangle x_{\tau_2}(k)\right)}} - \left| \frac{y_{\tau_2}(k-1)}{e^{\left(-j\measuredangle x_{\tau_2}(k-1)\right)}} \right| \tilde{s}(k) \right\|^2 \quad (31)$$

Considering $\left[x_{\tau_t}(k)\right]_r and \left[\tilde{s}_{\tau_t}(k)\right]_r$ and using M-PSK constellations of the set of $\tilde{s}_{\tau_t}(k)$ can be found corresponding to the receiving terminals τ_t, where $\left[x_{\tau_t}(k)\right]_r \in S_t$ and $\left[\tilde{s}_{\tau_t}(k)\right]_r \in S_t$.

2.3. Differential beamforming using power allocation strategy

From (2), (3), (4), (20) and (21) discussed earlier, the r^{th} relay broadcasts to the receiving terminals the following two signals $b_{R1,r}$ and $b_{R2,r}$, given by:

$$b_{R1,r} = \gamma_{R1,r} \tilde{s}_{\tau_1}(k)\, e^{-j\measuredangle g_r(k)} e^{-j\measuredangle x_{\tau_2}(k)} \quad (32)$$

where $\gamma_{R1,r} = \left| \frac{y_{R1,r}(k)\, e^{j\measuredangle(y_{R1,r}(k-1))}}{\sqrt{P_{\tau 1}}} \right| \cong |f_r(k)|$. Similarly, $b_{R2,r}$ can be written as follows:

$$b_{R2,r} = \gamma_{R2,r} \tilde{s}_{\tau_2}(k)\, e^{-j\measuredangle f_r(k)} e^{-j\measuredangle x_{\tau_1}(k)} \quad (33)$$

where $\gamma_{R2,r} = \left| \frac{y_{R2,r}(k)\, e^{j\measuredangle(y_{R2,r}(k-1))}}{\sqrt{P_{\tau 2}}} \right| \cong |g_r(k)|$. Similarly, in the third and fourth time slots of the k^{th} transmission block, the signal is received at the two terminals τ_1 and τ_2 can be expressed as:

$$y_{\tau_1}(k) = \sum_{r=1}^{R} f_r(k) b_{R2,r}(k) + \eta_{\tau_1}(k) \tag{34}$$

$$y_{\tau_2}(k) = \sum_{r=1}^{R} g_r(k) b_{R1,r}(k) + \eta_{\tau_2}(k) \tag{35}$$

where $\eta_{\tau_1}(k) and\ \eta_{\tau_2}(k)$ are the noise signals at the two receiving terminal $\tau_1\ and\ \tau_2$ in respect to the k^{th} block. Assuming high SNR, (34) and (35) can be rewritten as:

$$y_{\tau_1}(k) \cong \sum_{r=1}^{R} \sqrt{\frac{P_{Rr}}{P_{\tau_2}+1}} |f_r(k)||g_r(k)| e^{\left(-jx_{\tau_1}(k)\right)} s_{\tau_2}(k) + w_{\tau_1} \tag{36}$$

$$y_{\tau_2}(k) \cong \sum_{r=1}^{R} \sqrt{\frac{P_{Rr}}{P_{\tau_1}+1}} |f_r(k)||g_r(k)| e^{\left(-jx_{\tau_2}(k)\right)} s_{\tau_2}(k) + w_{\tau_2} \tag{37}$$

The expression of the maximum likelihood (ML) decoder while recovering the transmitted signal at the first receiving terminal τ_1, can be expressed as:

$$\arg\min_{\tilde{s}(k)} \left\| \frac{y_{\tau_1}(k)}{e^{\left(-j\measuredangle x_{\tau_1}(k)\right)}} - \left| \frac{y_{\tau_1}(k-1)}{e^{\left(-j\measuredangle x_{\tau_1}(k-1)\right)}} \right| \tilde{s}(k) \right\|^2 \tag{38}$$

Similarly, the decoder can be performed to recover the transmitted signal at the second receiving terminal τ_2. Where, $s_{\tau_1}(k)$ is decoded as:

$$\arg\min_{\tilde{s}(k)} \left\| \frac{y_{\tau_2}(k)}{e^{\left(-j\measuredangle x_{\tau_2}(k)\right)}} - \left| \frac{y_{\tau_2}(k-1)}{e^{\left(-j\measuredangle x_{\tau_2}(k-1)\right)}} \right| \tilde{s}(k) \right\|^2 \tag{39}$$

Considering $\left[x_{\tau_t}(k)\right]_r and \left[\tilde{s}_{\tau_t}(k)\right]_r$ and using M-PSK constellations of the set of $\tilde{s}_{\tau_t}(k)$ can be found corresponding to the receiving terminals τ_t, where $\left[x_{\tau_t}(k)\right]_r \in S_t\ and \left[\tilde{s}_{\tau_t}(k)\right]_r \in S_t$.

3. RESULTS AND ANALYSIS

Figure 2 to Figure 4 show the performance of a wireless relay network using $R = 2$; under an independent flat Rayleigh fading channels, and equally power distributed through communicating terminals and relay nodes which is given as $P_1 = P_2 = \sum_{r=1}^{R} P_{R_r}$. In addition, the total power can be expressed as $P_T = P_1 + P_2 + \sum_{r=1}^{R} P_{R_r}, P_{R_1} = P_{R_2} = \cdots = P_{R_r}$. Figure 2 and Figure 3 show a 3 dB performance difference between coherent and differential techniques using binary PSK (BPSK) and quadrature PSK (QPSK) modulation, AF protocol, and two relays. This is because differential techniques do not require the knowledge of CSI at any node and can be applied in fast fading channels.

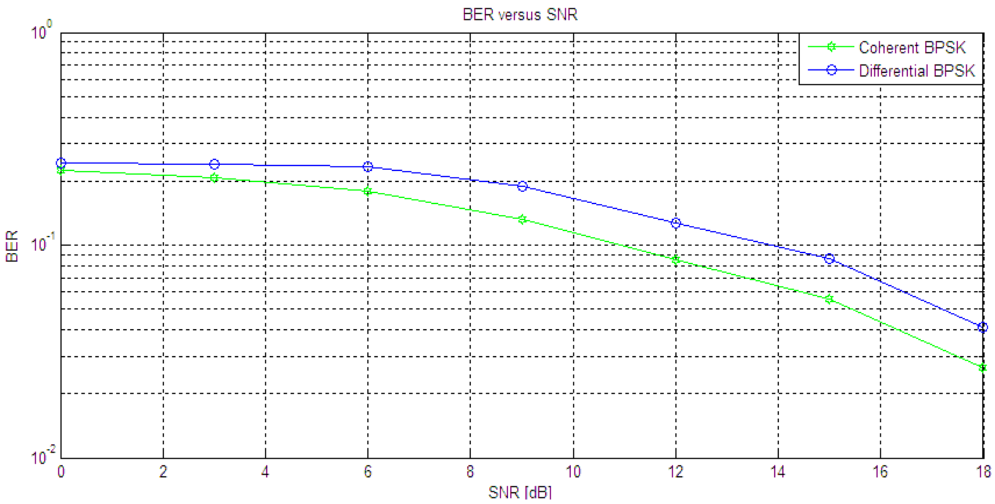

Figure 2. Comparison of coherent and differential techniques using BPSK modulation and 2 relays

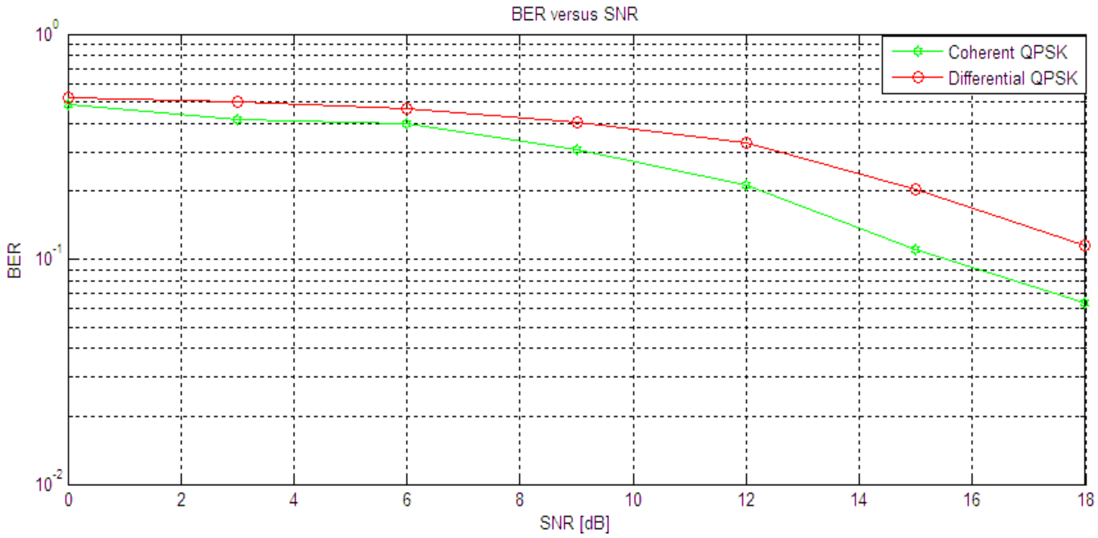

Figure 3. Comparison of coherent and differential techniques using QPSK modulation and 2 relays

Figure 4 shows the BER performance versus SNR using distributed beamforming technique in the presence of two and four relay-nodes, and each of the relay-nodes has a single antenna. The figure uses 16-PSK modulation and compares a four-phase differential beamforming scheme under power allocation and when using equal power distribution. From this figure, we can observe that the technique with power allocation shows improved performance compared to the technique with equal power distribution.

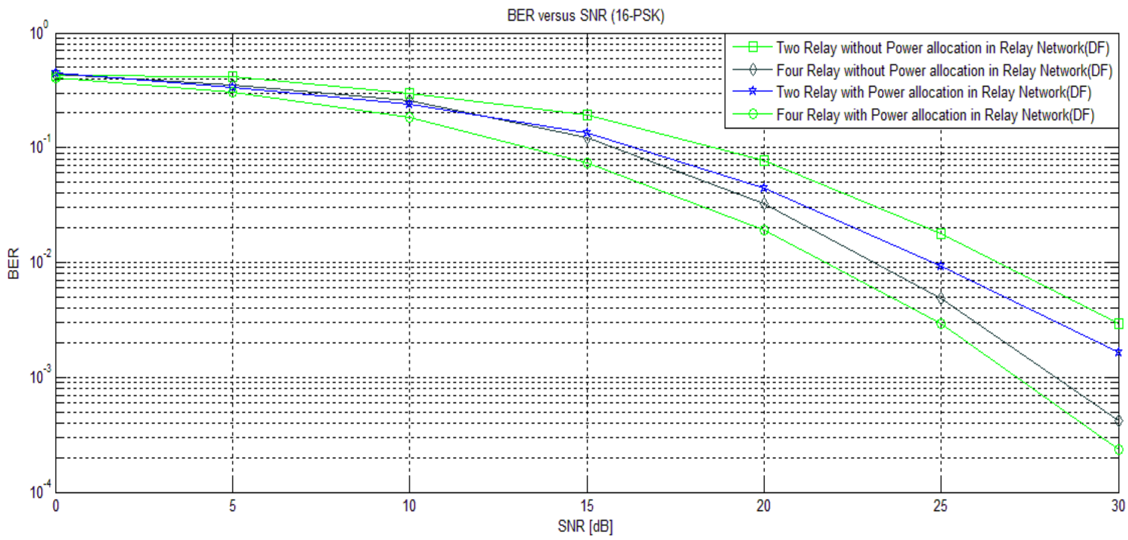

Figure 4. Power allocation in distributed relay network (R = 2 and 4) using 16-PSK

4. CONCLUSION

The idea of proposing a cooperative diversity technique for wireless relay networks is to improve the overall system performance in terms of either BER or achievable data rate with low decoding complexity and delay, and to transmit and decode the information symbols without needing CSI at either side of the communicating parties to overcome the overhead associated with estimating channel information. Therefore, in this work, we have suggested a distributed differential beamforming technique with power allocation to be used for two-way wireless relay networks. The proposed technique improves the overall system performance in terms of BER with low decoding complexity and delay without requiring CSI at any transmitting or receiving antenna.

REFERENCES

[1] S. Alabed and M. Pesavento, “A simple distributed differential transmit beamforming technique for two-way wireless relay networks,” in *The 16th International ITG Workshop on Smart Antennas (WSA 2012)*, Dresden, Germany, pp. 243-247, Mar. 2012.

[2] A. Schad, et al., “Bi-directional differential beamforming for multi-antenna relaying,” *40th IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP)*, pp. 2884-2888, 2015.

[3] S. Alabed, “Performance analysis of differential beamforming in decentralized networks,” *International Journal of Electrical and Computer Engineering (IJECE)*, vol, 8, no. 3, pp. 1692-1700, 2018.

[4] S. Alabed, et al., “Non-coherent distributed space-time coding techniques for two-way wireless relay networks,” *Signal Processing*, vol. 93, no. 12, pp. 3371-3381, 2013.

[5] S. Alabed, et al., “A low complexity decoder for quasi-orthogonal space-time block codes,” *IEEE Transactions on Wireless Communication*, vol. 10, no. 3, pp. 988-994, 2011.

[6] S. Alabed, et al., “Distributed differential space–time coding techniques for two-way wireless relay networks,” in *Proceedings of the Fourth IEEE International Workshop on Computational Advances in Multi-Sensor Adaptive Processing (CAMSAP 11)*, San Juan, Puerto Rico, pp. 221-224, Dec. 2011.

[7] S. Alabed, et al., “A simple distributed space-time coded strategy for two-way relay channels,” *IEEE Transactions on Wireless Communications*, vol. 11, no. 4, pp. 1260-1265, Apr. 2012.

[8] S. Alabed, et al., “Distributed Differential Space-Time Coding for Two-Way Relay Networks using Analog Network Coding,” *The 21st European Signal Proceedings Conference (EUSIPCO'13)*, Marrakech, Morocco, pp. 1-5, 2013.

[9] S. Alabed, “Performance Analysis of two-way DF Relay Selection Techniques,” *ICT Express*, vol. 2, no. 3, pp. 91-95, 2016.

[10] Adeeb Salh, et al., “Adaptive antenna selection and power allocation in downlink massive MIMO systems,” *International Journal of Electrical and Computer Engineering (IJECE)*, vol. 7, no. 6, pp. 3521-3528, Dec. 2017.

[11] S. Alabed, “Performance Analysis of Bi-Directional Relay Selection Strategy for Wireless Cooperative Communications,” *EURASIP Journal on Wireless Communications and Networking*, vol. 2019, no. 1, pp. 1-11, 2019.

[12] Yasmine Tabra, et al., “Hybrid MVDR-LMS beamforming for massive MIMO,” *Indonesian Journal of Electrical Engineering and Computer Science (IJEECS)*, vol. 16, no. 2, pp. 715-723, Nov. 2019.

[13] W. Duan, et al., “Effective Resource Utilization Schemes for Decode-and-Forward Relay Networks With NOMA,” in *IEEE Access*, vol. 7, pp. 51466-51474, 2019.

[14] J. Ju, et al., “Performance Analysis for Cooperative NOMA With Opportunistic Relay Selection,” in *IEEE Access*, vol. 7, pp. 131488-131500, 2019.

[15] G. Cai, et al., “Design and analysis of relay-selection strategies for two-way relay network-coded DCSK systems,” *IEEE Transactions on Vehicular Technology*, vol. 67, no. 2, pp. 1-13, 2017.

[16] T. N. Nguyen, et al., “Performance Enhancement for Energy Harvesting Based Two-Way Relay Protocols in Wireless Ad-Hoc Networks With Partial and Full Relay Selection Methods,” *Ad Hoc Networks*, vol. 84, pp. 178-187, 2019.

[17] X. Wen, et al., “Rank-two beamforming for single-group multicasting networks using OSTBC,” *The 7th IEEE Sensor Array and Multichannel Signal Processing Workshop (SAM)*, pp. 65-68, Jun. 2012.

[18] D. Taleb, et al., “Optimal general-rank transmit beamforming technique for multicasting service in modern wireless networks using STTC,” *Proceedings of the 19th International IEEE/ITG Workshop on Smart Antennas (WSA 2015)*, Ilmenau, Germany, pp. 1-7, Mar. 2015.

[19] S. Alabed, “A computationally efficient detector for MIMO systems,” *International Journal of Electrical and Computer Engineering (IJECE)*, vol. 9, no. 5, pp. 4138-4146, Oct. 2019.

[20] A. M. Elshirkasi, et al., “Performance evaluation of 2-port MIMO LTE-U terminal antenna with user’s hand effect,” *Bulletin of Electrical Engineering and Informatics*, vol. 8, no. 1, pp. 158-165, Mar. 2019.

[21] D. H. Ai, “Average Channel Capacity of Amplify-and-forward MIMO/FSO Systems Over Atmospheric Turbulence Channels,” *International Journal of Electrical and Computer Engineering (IJECE)*, vol. 8, no. 6, pp. 4334-4342, Dec. 2018.

[22] M. I. Youssif, et al., “Image multiplexing using residue number system coding over MIMO-OFDM communication system,” *International Journal of Electrical and Computer Engineering (IJECE)*, vol. 9, no. 6, pp. 4815-4825, Dec. 2019.

[23] S. Pyla, et al., “Performance Analysis of Adaptive Filter Channel Estimated MIMO OFDM Communication System,” *International Journal of Electrical and Computer Engineering (IJECE)*, vol. 8, no. 5, pp. 3829-3838, Oct. 2018.

[24] P. Sagar and B. Jaymin, “Near Optimal Receive Antenna Selection Scheme for MIMO System under Spatially Correlated Channel,” *International Journal of Electrical and Computer Engineering (IJECE)*, vol. 8, no. 5, pp. 3732-3739, Oct. 2018.

[25] A. Salh, et al., “Maximizing Energy Efficiency for Consumption Circuit Power in Downlink Massive MIMO Wireless Networks,” *International Journal of Electrical and Computer Engineering (IJECE)*, vol. 7, no. 6, pp. 2977-2985, Dec. 2017.

[26] P. Larsson, et al., ”Coded bi-directional relaying,” in *Proceedings IEEE Vehicular Technology Conf*erence, vol. 2, pp. 851-855, 2006.

[27] M. F. Ghanim, "The effect of wavelet transform on OFDM system in modern cellular networks," *Indonesian Journal of Electrical Engineering and Computer Science (IJEECS)*, vol. 15, no. 1, pp. 324-327, Jul. 2019.
[28] P. Van-Duc, et al., "Outage probability analysis of DF PSR energy harvesting full-duplex relaying network with presence of the direct link using MRC technique," *Indonesian Journal of Electrical Engineering and Computer Science (IJEECS)*, vol. 16, no. 2, pp. 606-613, Nov. 2019.
[29] S. Alabed, "Non-coherent Distributed Beamforming in Decentralized Two-Way Relay Networks," *IEEE canada, Canadian Journal of Electrical and Computer Engineering*, 2020.

BIOGRAPHIES OF AUTHORS

Samer Alabed is an associate professor of electrical engineering at the college of engineering and technology, American University of the Middle East, Kuwait and IEEE senior member. He worked also in the communication systems group at Darmstadt University of Technology, Darmstadt, Germany from 2008 to 2015. He received his PhD degree in electrical engineering and information technology, from Darmstadt University of Technology, Darmstadt, Germany. During the last 17 years, he has worked as an associate professor, assistant professor, (post-doctoral) researcher, and lecturer in several universities in Germany and Middle East and supervised tens of master students and several PhD students. He received several awards from IEE, IEEE, DAAD ... etc., such as the best paper award from the International IEEE WSA and was invited to many conferences and workshops in Europe, US, and North Africa. The main idea of his research is to develop advanced DSP algorithms in the area of wireless communications including (Massive) MIMO systems, distributed systems, co-operative communications, relay networks, space-time block and trellis coding, differential and blind techniques, channel coding, two-way relaying, baseband communications, multi-carrier transmission, modeling of channel characteristics, adaptive beamforming, sensor array processing, transceiver design, multi-user and multi-carrier systems, convex optimization, channel equalization, and other kinds of distortion and interference mitigation. Further information are available on his homepage: http://drsameralabed.wixsite.com/samer

Issam Maaz joined American University of the Middle East as an assistant professor of electrical and computer engineering in 2017. He received his PhD degree in electronics and communication engineering with great honor from Telecom ParisTech, Paris, France, in 2015. During the last few years, he has worked as an assistant professor, and research engineer in several companies such as Orange France and worked on several European projects such as SHARING CelticPlus. The main idea of his research is to develop new channel modeling and channel estimation for heterogeneous networks, small cells, MIMO systems, Radio Environmental Maps (REM), etc, that can be used for the new generations of communication systems such as 5G and beyond.

Mohammad Al-Rabayah holds a PhD in electrical engineering from the University of New South Wales (UNSW) since the year 2011. A master's degree in telecommunications from UNSW in the year 2005, and a bachelor of science in electrical engineering from Jordan University of Science and Technology (JUST) in 2003. He is currently an assistant professor at the department of electrical engineering at the American University of Middle East (AUM) – Kuwait, since 9/2018. He is teaching various courses for the undergraduate students, supervising their graduation projects, an academic advisor for electrical engineering students, and a member of many committees at the department level responsible for maintaining high level of education and research at the department. Al-Rabayah also worked as an assistant professor at Prince Sultan University (PSU), Riyadh-KSA, for the period between 8/2015 and 8/2018. Dering his time at PSU he taught many courses at the communications and networks department, supervised undergraduate students during their six months training internships inside and outside KSA, and participated in many training workshops to develop his professional career, and to support the university efforts toward gaining the international engineering accreditation ABET. He worked as an assistant professor at Prince Sattam bin Abdulaziz University (PSAU), Kharj- KSA, in the period between 10/2014 and 6/2015. His current research is in the fields of wireless networks, and cooperative wireless communications.