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Efficient Energy Allocation Method for Symmetrical Relay Communication in Cooperative Mode

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Abstract: Most of the wireless devices (i.e. mobile handsets, laptops, tablets etc.) are designed with only one antenna, especially due to hardware limitations, size and cost factors; cooperative communication can be used to generate transmit diversity [1]. This enables single antenna wireless devices to share their resources during communication in such a manner that creates a Virtual MIMO (Multiple-Input and Multiple-Output) system [2-3]. Major challenges are Resource sharing, Communication Strategies, Energy Efficiency, Range and Security [4-5]. This paper considers the problem of how efficiently to allocate transmission energy in a wireless communication system with two delay-constrained cooperating sources and one destination. The sources in the system are assumed to cooperate via the Orthogonal Amplify-and-Forward (OAF) protocol. The channels are assumed to be flat fading and the sources are each required to satisfy an outage probability constraint. The analysis focuses on optimum energy allocation and energy efficiency for different channel state information under different set of assumptions.

Keywords: Co-operative Communication, Amplify and Forward Relaying technique, Multiple Input Multiple Output Systems, Transmit Diversity, Adhoc Networks, Orthogonal AF Relaying, Channel State Information (CSI) etc

I. INTRODUCTION

As demand for new smart wireless services and applications increases, a significant focus is on the further development of wireless communication networks, so that the required high throughput and energy efficiency will be provided. However, the wireless signal transmission imposes serious challenges in fulfilling those demands, due to the complex nature of wireless radio channel. Thus, in defining the adequate technical solutions for future broadband wireless networks, all relevant characteristics of this specific transmission medium have to be taken into account. That is why research efforts have been directed towards new solutions and techniques that would support high data rates and higher capacities of future wireless systems, with the better coverage and energy efficiency at the same time. Energy allocation for amplify-and-forward cooperation was analysed with the goal of minimizing BER in [1], minimizing total power subject to a rate constraint in [3], respectively. Minimum outage probability energy allocation has also been considered for a hybrid protocol [4]. While considered the impact of partial channel state information (specifically, the instantaneous channel amplitudes) at the transmitters on the outage probability performance of the decode-and-forward protocol [5], the impact of channel state information on amplify-and-forward has not been studied. Zhao et al. consider optimum energy allocation for the amplify-and-forward protocol. Resource allocation in refers specifically to the notion of transmit energy allocation and this notion of resource allocation is expanded to also include protocol timeslot allocation in [7-8] to minimize the outage probability, however, there is a mathematical error in their main result. This paper considers the problem of optimum energy allocation and energy efficiency of the amplify-and-forward protocol in four different scenarios: (i) both the sources and the destination have access to the full channel state information; (ii) the sources have access to only the channel statistics and the destination have access to the full channel state information; (iii) the sources have access to the full channel state information and the destination has no channel state information and (iv) the sources have access to only the channel statistics and the destination has no channel state information.

II. PROPOSED SYSTEM MODEL

An Efficient allocation of transmission energy in a wireless communication system with two sources (delay constrained) and one receiver is considered in this paper.

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Assumptions:

Sr.No.	Assumption
1	Orthogonal Amplify-and-forward protocol.
2	Channels are flat fading
3	Sources are required to satisfy outage probability constraint

The system model shown in Figure 1 below:

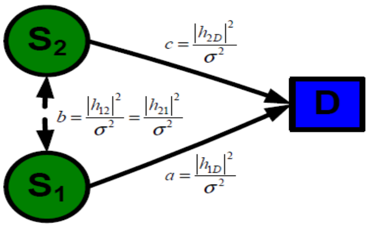

Figure 1: Two-source one-destination cooperative transmission system model.

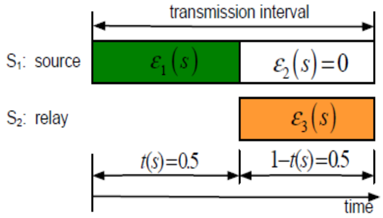

Figure 2: Orthogonal amplify-and-forward protocol.

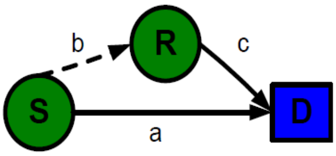

Figure 3: One-source, one-relay, one-destination model.

Each source is assumed to transmit in an orthogonal sub channel (e.g. FDMA) and send distinct data to the destination and cooperate via the “orthogonal amplify-and-forward” protocol first described in [1] as shown in Figure 2 above. We assume a half-duplex relay and normalize the time period for each symbol out of N symbols to 1 unit. The two-source orthogonal amplify-and-forward cooperative transmission protocol divides the transmission interval into two time-slots of equal duration. Each source transmits its own information in the first timeslot (while receiving the transmission of the other source) and the second timeslot is used for cooperative retransmission of the signal received during the first timeslot. The channels are assumed to be flat and block-fading where their value is randomly generated but remains constant over the both timeslots in the cooperative frame. Note that each source transmits while receiving the transmission of the other source in the first timeslot. The sources operate in half-duplex mode, however, in the sense that transmission and reception does not occur simultaneously in any orthogonal sub channel.

Normalized Channel gains in Co-operative Communication System can be indicated as follows:

$a = |h_{1D}|^2/\sigma^2,\ b = |h_{21}|^2/\sigma^2 = |h_{12}|^2/\sigma^2,\ c = |h_{2D}|^2/\sigma^2$

Where,
σ^2 = Variance of Zero − mean Gaussian Noise in Channel

S=(a,b,c) ; a, b, c are iid exponentially distributed with individual means $\mu_{a,}\mu_{b,}\mu_c$ respectively.

Let $\mathcal{E}(s) = \big(\mathcal{E}_1(s), \mathcal{E}_2(s), \mathcal{E}_3(s), t(s)\big)$ is the resource allocation rule for all possible states s=(a,b,c),

Where,
$\mathcal{E}_1(s)$ – Source energy in first timeslot of duration t(s)
$\mathcal{E}_2(s)$ and $\mathcal{E}_3(s)$ –Transmission energies of the Source and the Relay respectively, in Second timeslot of duration 1- t(s), $0 < t(s) \leq 1$. Total transmission energy used in transmitting the information in i^{th} source to destination or receiver $\mathcal{E}_{Total} = (\mathcal{E}_1 + \mathcal{E}_2 + \mathcal{E}_3)$. However in Orthogonal Amplify and Forward protocol, $\mathcal{E}_2(s) = 0$ and t(s)=0.5.

$\Omega = \{\mathcal{E}(s) : \mathcal{E}_1(s) \geq 0, \mathcal{E}_2(s) \geq 0, \mathcal{E}_3(s) \geq 0, 0 < t(s) \leq 1\}$.

F(s) indicates PDF of channel states, then long duration average total transmit energy constraint cab be expressed as

$$E[\mathcal{E}_{Total}(s)] \triangleq \int_s [\mathcal{E}_1(s) + \mathcal{E}_2(s) + \mathcal{E}_3(s)]\, dF(s) \leq \varepsilon_{Total}$$

$\bar{\Omega}$ is subset of Ω $\quad \bar{\Omega} = \{ \mathcal{E}(s) : E[\mathcal{E}(s)] \leq \mathcal{E}_t, \mathcal{E}(s) \in \Omega \}$.

min $P_{out,}$ such that $\mathcal{E}(s) \in \bar{\Omega}$

min $E[\mathcal{E}_{Total}(s)]$, such that $P_{out} \leq p$

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III. PROPOSED ALGORITHM AND IT'S PROCESSING AT DESTINATION AND SNR ANALYSIS

The performance measure considered in this section is outage probability, characterized as the probability that the SNR of the source's data at the destination falls underneath a deterministic limit ρ, i.e.

$$P_{out} = \text{Probability [outage]} = \text{Probability [SNR} < \rho]$$

The SNR of the sources' data at the destination node is resolved not just by the channel states and the transmission energies yet additionally by how the goal frames its choice measurement from the got source and transfer transmissions. To more readily separate the impact of channel state data at the source and transfer, we initially expect that the destination has full access to the channel states and transmit energies of both sources in both timeslots and utilizations maximal ratio combining (MRC) of the significant source/transfer perceptions in both timeslots to augment the SNR of the choice measurement. At the point when the source and relay approach full CSIT, they can progressively designate their transmission energies as indicated by the momentary divert amplitudes in each transmission interim. The subsequent prompt SNR at the destination, after MRC, can be communicated as

$$\mathrm{SNR}_1 = a\mathcal{E}_1 + \frac{(b\,\mathcal{E}_1\,c\,\mathcal{E}_3)}{(1+b\,\mathcal{E}_3+c\,\mathcal{E}_3)} \qquad 1.$$

At the point when the source and transfer do not approach the channel state, they cannot progressively allot their transmission energies in every transmission interim. They should choose a settled transmission energy dependent on knowledge of the channel measurements. The subsequent prompt SNR at the destination, after MRC, can be communicated as

$$\mathrm{SNR}_2 = a\mathcal{E}_1 + \frac{(b\,\mathcal{E}_1\,c\,\mathcal{E}_3)}{(1+\mu_b\,\mathcal{E}_1+c\,\mathcal{E}_3)} \qquad 2.$$

It might be surprising that (1) and (2) seems, by all accounts, to be relatively indistinguishable, the main contrast being the expectation in the denominator of (2). In the two cases, the instant SNR at the goal is completely determined by the standardized channel amplitudes and transmit energies. The major contrast among (1) and (2), in any case, is in how the transmit energies E1 and E3 are chosen. In (1), the transmit energies are the elements of the present channel expresses a, b, and c while, in (2), these energies depend just on learning of the channel measurements, e.g., μa, μb, and μc. The accompanying areas investigate the noteworthiness of this distinction in wording of ideal energy distribution methodologies and the energy effectiveness of the two-source agreeable transmission framework [11-12]. Presently we expect CSI is not accessible at the destination, subsequently MRC cannot be utilized. One methodology in this situation is to combine the perceptions with equivalent gain, i.e. EGC. Here, full CSIT implies the source and the relay know the momentary channel amplitudes, the subsequent immediate SNR at the destination, after EGC, can be communicated as

$$\mathrm{SNR}_2 = \frac{a\mathcal{E}_1}{2} + \frac{c\,\mathcal{E}_1\;\mathcal{E}_3\left(b-\frac{c}{2}\right)+2\,\mathcal{E}_1(abc\,\mathcal{E}_3\Psi)^{\frac{1}{2}}}{(2\Psi+c\,\mathcal{E}_3)} \qquad 3.$$

While when the source and transfer don't approach the channel express, the coming about immediate SNR at the goal, after EGC, can be communicated as

$$\mathrm{SNR}_4 = \frac{\mathcal{E}_1(\sqrt{a}+\sqrt{bc\Psi})^2}{(2+\Psi)} \qquad 4.$$

The accompanying segments analyse ideal energy assignment procedures and energy efficiency of the two-source agreeable transmission framework dependent on equation (3) - (4).

A. Optimum Energy Allocation For Oaf With Full Csit/Csir

For energy assignment analysis for general p > 0, we initially consider the situation when p = 0. The issue for this situation is to choose a energy allotment $\{\mathcal{E}_1, \mathcal{E}_3\}$ to such an extent that $\mathrm{SNR}_1 \geq \rho$ clearly. Since the source and relay have access to immediate channel amplitudes [13], they can progressively apportion their transmission energies to such an extent that the arbitrariness instigated by the direct state in SNR_1 is evacuated such that $\mathrm{SNR}_1 = \rho$. There are, nonetheless, a boundless number of energy allotments that fulfill $\mathrm{SNR}_1 = \rho$. The space of allowable energy assignments fulfilling $\mathrm{SNR}_1 = \rho$ can be portrayed as the locale in R2 where $\mathcal{E}_3 \geq 0$ and ρ / a+b < $\mathcal{E}_1 \leq \rho$ / a , where the upper limit to E1 compares to the situation when $\mathcal{E}_3 = 0$ (coordinate transmission or, proportionately, no collaboration) and as far as possible compares to the situation when $\mathcal{E}_3 \rightarrow \infty$ (endless participation). On account of direct transmission, the aggregate energy required to meet the SNR target is $\mathcal{E} = \mathcal{E}_1 = \rho$ / a . Prior to inferring the ideal (least aggregate energy $\mathcal{E}_1 + \mathcal{E}_3$) helpful cooperative energy allocation methodology in this situation, we initially consider the

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topic of when is it more proficient for the relay node to not transmit. This is made formal in the accompanying recommendation.

Recommendation 1. There exists $\mathcal{E}_{\text{Total}} < \frac{\rho}{a}$ if and only if $\frac{c}{a} > 1 + \frac{a}{b\rho}$ 5.

Proof:

$\text{SNR}_1 = \rho$ can be reproduced as

$$\mathcal{E}_{\text{Total}} = (\mathcal{E}_1 + \mathcal{E}_3) = \mathcal{E}_1 + \frac{[b\ \mathcal{E}_1{}^2\, a + (a-b\rho)\,\mathcal{E}_1 - \rho]}{[c(\rho-(a+b)\,\mathcal{E}_1)]} \qquad 6.$$

First and second derivative at $\mathcal{E}_1 = \left(\frac{\rho}{a}\right)$ gives:

$$\mathcal{E}_{\text{Total}}^{1} = \frac{\partial}{\partial \mathcal{E}_1}\mathcal{E}_{\text{Total}}\left(\frac{\rho}{a}\right) = 1 - \frac{a(a+b\rho)}{cb\rho} \qquad 7.$$

$$\mathcal{E}_s^{*} = \frac{\rho}{a+b} + \frac{((1-\alpha)\rho b)^{\frac{1}{2}}\ (a+(1+\rho)b)^{\frac{1}{2}}}{(a+b)\ (\alpha c(a+b)-(1-\alpha)ba)^{\frac{1}{2}}} \qquad 8.$$

$\mathcal{E}_s^{*}$ is implied and given through $\text{SNR}_1 = \rho$ as Cumulative Distribution Function of $\mathcal{E}_{\text{Total}}^{*}$ satisfying $\text{SNR}_1 = \rho$ as

$F_{\mathcal{E}_{\text{Total}}^{*}}(x) = \text{Prob}[\mathcal{E}_{\text{Total}}^{*} \leq x]$. It is proved that when $\frac{c}{a} = 1 + \frac{a}{b\rho}$, the CDF reduces to $\mathcal{E}_1^{*} = \frac{\rho}{a}$ and $\mathcal{E}_3^{*} = 0$, as implied by above proposition.

We take note of that this is basically a deft transmission technique where the source and relay maintain a strategic distance from transmission (and cause a blackout) in situations when the channel state is troublesome. The outage probability necessity is fulfilled under this technique since the SNR at the goal will be equivalent to ρ with probability (1- p) and equivalent to zero generally [11-15].

B. Optimum Energy Allocation For Oaf With Full Csit And No Csir

Till now work in asset distribution of helpful remote transmission frameworks has concentrated on the effect of the helpful convention and CSIT. In this area, we accept both the source and transfer approach full CSIT and determine the ideal energy allotment methodology for equivalent gain joining (EGC) to investigate the effect of collector decent variety joining on ideal energy distribution and in general energy proficiency [12-14]. Utilizing indistinguishable methodology from in area (4), we initially consider the case p = 0. In this case, the relay hub energy $\mathcal{E}_3$can be composed as a component of ρ and $\mathcal{E}_1$ by fathoming (3) for $\mathcal{E}_3$when $\text{SNR}_3 = \rho$. Note that (3) is is quadratic in $\mathcal{E}_3$. The two roots for $\mathcal{E}_3$ can be composed as a

$$\mathcal{E}_{3_{1,2}} = \frac{(b\mathcal{E}_1+1)(b\mathcal{E}_1{}^2\, a + 2b\rho\,\mathcal{E}_1 + a\rho\mathcal{E}_1 - 2\rho^2)}{c(\rho - b\mathcal{E}_1)^2} \pm \frac{2\mathcal{E}_1\sqrt{ab\rho(2b\mathcal{E}_1 + a\mathcal{E}_1 - 2\rho)}}{c(\rho - b\mathcal{E}_1)^2} \qquad 9.$$

Denote the admissible range of $\mathcal{E}_1$ as A. $\mathcal{E}_3$ must be decreasing function of $\mathcal{E}_1$ on A, the correct root of $\mathcal{E}_{3_{1,2}}$ must be $\mathcal{E}_{3_2}$.

$$\mathcal{E}_3 = \frac{(b\mathcal{E}_1+1)(b\mathcal{E}_1{}^2\, a + 2b\rho\,\mathcal{E}_1 + a\rho\mathcal{E}_1 - 2\rho^2)}{c(\rho - b\mathcal{E}_1)^2} - \frac{2\mathcal{E}_1\sqrt{ab\rho(2b\mathcal{E}_1 + a\mathcal{E}_1 - 2\rho)}}{c(\rho - b\mathcal{E}_1)^2} \qquad 10.$$

And total energy is $\mathcal{E}_{\text{Total}} = (\mathcal{E}_1 + \mathcal{E}_3)$ to meet the condition that $\text{SNR}_3 = \rho$.

Problem can be formulated as: $\mathcal{E}_1^{*} = \arg\ \min_{\mathcal{E} \in A} \mathcal{E}_{\text{Total}}$

Solution to this problem is supported by following results.

Recommendation 2: Total energy $\mathcal{E}_{\text{Total}}$ is a convex function of $\mathcal{E}_1$ on A

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Proof:

$$\frac{\partial^2 \mathcal{E}_{\text{Total}}}{\partial \mathcal{E}_1^2} = \frac{b\rho f(y)}{2c(b\mathcal{E}_1-\rho)^4\,(ab\rho(2b\mathcal{E}_1+a\mathcal{E}_1-2\rho))^{\frac{3}{2}}} \geq 0. \qquad 11.$$

Function $f(y) = \frac{(y-\rho a)^4\, r(y)}{(2b+a)^2\rho^3 a^2}$ where; $y=\sqrt{ab\rho(2b\mathcal{E}_1 + a\mathcal{E}_1 - 2\rho)}$ 12.

$b\rho \geq 0$ and denominator is nonnegative value on A.

Hence, $\frac{\partial^2 \mathcal{E}_{\text{Total}}}{\partial \mathcal{E}_1^2} \geq 0$ on A $\Leftrightarrow$ $r(y) \geq 0$ on C where $c = [0, 2b\rho]$

The function of $r(y)$ can be written as,

$$r(y) = y^4 + 4a\rho y^3 + (12\rho^2 ab + 3\rho a^2 + 6\rho ab)y^2 + \ldots\ldots\ldots + 4a^2b^2\rho^4 + 2a^3b\rho^3 + 4a^2b^2\rho^3 \qquad 13.$$

IV. EXPERIMENTAL ANALYSIS

The numerical results on energy efficient OAF Cooperative Communication for each type is discussed here. Comparative analysis is also presented to quantify the value of CSI on energy efficiency of OAF Cooperative transmission.

Full CSIT/CSIR versus no CSIT/CSIR

This segment presents numerical models showing the effect of CSIT on cooperative energy allocation and efficiency when Rayleigh Fading channels as shown in Figure 3 are considered and acting independently. The majority of the outcomes in this segment accept µb=100, and ρ = 10dB. Graphs below in Figures 6 and 7 indicates about the case at the point when the relay has a measurably advantaged channel to the destination, i.e. µc = 100 what's more, µa = 10.

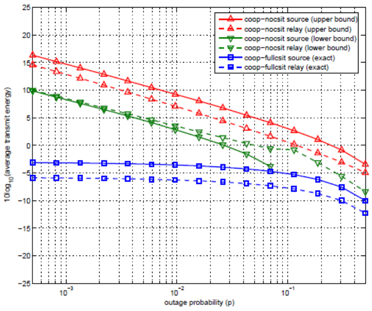

Figure 4: Energy allocation when Relay is working as efficient channel to destination. Source does not transmit in lower bound.

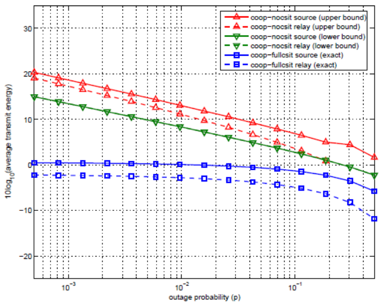

Figure 5: Energy allocation when Source/ Relay is working as symmetric channel to destination. Source and Relay Transmit equal energy towards Destination.

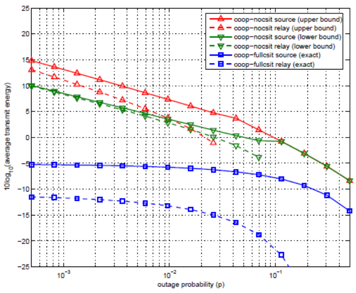

Figure 6: Energy allocation when Relay is working as inefficient channel to destination. Relay does not transmit in lower bound.

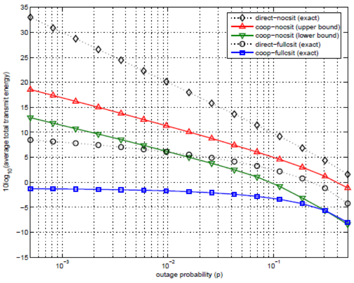

Figure 7: Average of total energy of Direct and cooperative transmission when relay transmission is efficient to destination. Rayleigh Fading Channel.

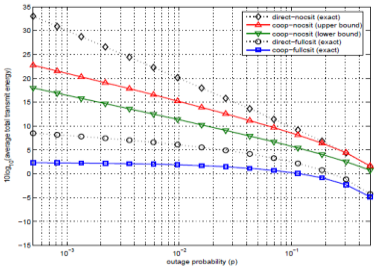

Figure 8: Average of total energy of Direct and cooperative transmission when relay transmission is symmetric and independent Rayleigh channels to destination.

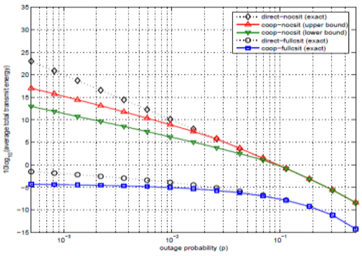

Figure 9: Average of total energy of Direct and cooperative transmission when relay transmission is inefficient and independent Rayleigh channels to destination.

Figures 4 and 8 shows the situation when the source and transfer confront measurably symmetric free Rayleigh blurring channels to the destination, i.e. μc = μa = 10. In figures 5 and 9, we consider the situation when the transfer has a factually distraught channel to the destination, i.e. μc = 10 and μa = 100. Figures 4, 5 and 6 demonstrate the ideal source/relay energy distributions to accomplish the outage probability target p for the situations when the transfer relay node faces advantaged, symmetric, and hindered channel to the destination individually. The outcomes appear, as expected, that agreeable transmission without CSIT accomplishes a settled outage probability with less aggregate energy than direct transmission without CSIT. Essentially, agreeable transmission with full CSIT accomplishes a settled outage probability with less add up to energy coordinate transmission with full CSIT. In the two cases, the energy increases tend to be expansive when the transfer has a measurably advantaged channel to the goal as well as p → 0. Figures 7, 8 and 9 likewise uncover the effect of full CSIT on the generally energy effectiveness the correspondence framework appeared in Figure 3. Both direct transmission what's more, helpful transmission are significantly increasingly productive when full CSIT is accessible [16-18]. It is to some extent surprise to note that direct transmission with full CSIT is more energy productive than cooperative transmission without CSIT in the majority of the cases considered. Actually when the transfer has a measurably symmetric or on the other hand hindered channel to the destination, the energy required for direct transmission with full CSIT is not exactly even the lower bound outcomes for agreeable transmission without CSIT for all p. For the situation when the relay has an a factually advantaged channel, the energy required for direct transmission with full CSIT is less than the upper headed outcomes for helpful transmission without CSIT for all p. These outcomes exhibit that a feedback channel giving full CSIT to a source may offer more benefit, at any rate as far as transmission energy proficiency in blurring channels, than participation without CSIT.

CONCLUSION

As per the discussion and analysis above, this paper examines the impact of channel state information (CSIT and CSIR) on optimum energy allocation and energy efficiency of a wireless communication system with 2 delay-constrained cooperating sources and one destination mistreatment the orthogonal amplify-and-forward protocol. The sources are each required to satisfy an outage probability constraint. An explicit optimum (minimum total energy) source/relay energy allocation strategy comes for the case once the sources have full CSIT (instantaneous channel amplitudes) and the destination has full CSIR/no CSIR. For the case without CSIT, outage probability bounds are derived. Numerical examples with freelance Lord Rayleigh attenuation channels demonstrate that full CSIT can significantly improve the energy efficiency of both cooperative and direct transmission. The results also suggest that, while cooperative transmission tends to have better energy efficiency than direct transmission, cooperative transmission without CSIT is often less energy efficient than direct transmission with full CSIT. We also analyze how the receiver diversity combining technique affects both the optimum energy allocation and the overall energy efficiency of orthogonal amplify-and-forward cooperative transmission systems. Our results show that, unlike MRC, optimum cooperative transmission with EGC continuously needs transmission by the relaying node.

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